ENGINEERING THE NEW AGE

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A CHALLENGE TO MANKIND TO ADOPT SIMPLE SCIENTIFIC TRUTHS IN BUILDING THE WORLD OF TOMORROW.

JOHN J. O'NEILL

SCIENCE EDITOR – *NEW YORK HERALD TRIBUNE*

AUTHOR OF YOU AND THE UNIVERSE

ENGINEERING THE NEW AGE

John J. O'Neill

What man can do, with the enormously expanded facilities at his command, to make his terrestrial home a better place to live in is the substance of this book.

"If we are going to do an engineering job on building a new age and a new world, it would be well to get firmly fixed in our minds the idea that it is a big one, and it will be necessary to proceed in the way an engineer would — by getting thoroughly acquainted with the site on which the construction work will be done, and with conditions in the neighborhood which will influence the planning, the building operations, and the use of the completed structure. The site upon which we are going to build is the earth, and its neighborhood is the universe. It is, perhaps, of even greater importance to the engineer to ascertain something about the people he is dealing with. The people, in this case, will comprise the human race and in particular that portion of it in the United States upon whom there has descended a responsibility for world leadership."

These are the author's words, the words of a man who, through his previous books and his weekly newspaper articles, has intrigued thousands of readers with his ability to apply the discoveries of the scientists to the present and future problems of daily living which concern us all.

ENGINEERING THE NEW AGE challenges the intelligent citizen to step up and play a part in building the world of tomorrow.

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ENGINEERING THE NEW AGE

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ENGINEERING THE NEW AGE

ALMIGHTY ATOM

YOU AND THE UNIVERSE

PRODIGAL GENIUS, The Life of Nikola Tesla

ENGINEERING THE NEW AGE

By John J. O'Neill

IVES WASHBURN, INC.
NEW YORK

Printed in the United States of America
By the Vail-Ballou Press, Inc., Binghamton, New York

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THE IDEA

ENGINEERING THE NEW AGE presents the story of the individual and the role he will play in the unfolding of the new era in which all of our resources will be directed toward human welfare. It presents the relationship of man to the cosmos, man to man, man to his community. It finds an underlying pattern which provides a blueprint for progress.

"There are tides in the affairs of men," and we are now at a low ebb. There is building up, however, a new concept which will raise this ebb to a flood of social advancement, which will carry civilization to new high levels of accomplishment. In this new concept the spirit of science, which is the source of its wonder-working powers, is linked to the practicability of engineering techniques which make advances in scientific knowledge available for our everyday uses, as the basis of a program for all fields of human activity, but one in which sensitivity to human values is the critical factor.

Science and engineering are the twin giant forces in the world today. Both of them, in their organized aspects, are lacking a social consciousness. Development in them of a social consciousness is the next major step in cultural progress. When it starts to function, it will provide an entirely new approach to our task of solving problems. It will bring to a close the era in which we had no more fixity of purpose than if we were riding a hurricane, and thereafter it will become inevitable that progress shall be planned on a universal pattern which has its origin in nature and is not subjected to alteration by the caprices of even powerful, political personalities.

Can we learn something about the characteristics of this uni-

versal pattern? And the possibilities of its being engineered for human welfare? The present work examines these problems and finds an affirmative answer, one which gives ample grounds for being optimistic about the results.

A situation will be brought about, however, in which the individual is found occupying an entirely new status in the universal scheme of things, one more befitting the higher dignity of his nature. It is one in which he will be loaded with new and great responsibilities but will have ample powers for handling them. This new vitalistic viewpoint concerning the nature of the individual and the greater potentialities of the human personality are undoubtedly the most significant development of this study.

In order to bring about a clearer understanding of the new, higher status of the individual as the central focal point of the cosmos, it is necessary to lay a foundation of knowledge on a broad base. To this end there is presented, in the opening chapters, a picture of the universe in which man has his roots, drawn in terms of the atomic energy concept, and, on the same basis, a survey of the planet he inhabits. It is a different universe and a different terrestrial sphere than the one with which we were familiar up to a few years ago for, literally, atomic energy has given us a new heaven and a new earth.

Since the new age described would remain something very abstract and have little meaning unless stated in terms of previous efforts to achieve cultural advancement, a quick survey is made of earlier civilizations from a viewpoint in which the significant achievements in utilizing resources for good or evil are recorded and the advances of permanent value indicated.

Man, in his individual variations, is both the greatest strength and greatest weakness of the human race; he is his own best friend and greatest enemy. In the early chapters, it is found quite desirable for man to end his isolation and accept the universe as a cosmos. In later chapters, it is found to be the part of wisdom to accept the human race, even in the light of full

knowledge of its virtues and deficiencies, since the evidence indicates that humanity is a very successful institution with vaster potentialities for harmonious development than we have heretofore suspected or utilized.

Man's handiwork, his cities, are examined and found (with some rare and redeeming exceptions) to be aggregates of gross and gaudy gadgetry supercharged with the viruses of rapid decay which will require their quick abandonment and the creation of a new constellation of cities built on a better idea and more in keeping with the spirit of the new age.

Reconstructing man's terrestrial homestead and readjusting the human race to functioning in harmony with its new ideals presents the most gigantic task man has ever undertaken. It is, however, well within his capabilities but calls for a new concept of organization and purpose.

The technique of demonstrated value in accomplishing tasks in the realm of material things is the engineering method. It is found equally applicable to projects involving human affairs. A survey is made of engineering as an organized entity within the social structure, of the engineer as an individual, and of the educational processes through which the engineer is produced. Opportunities are found for the application of engineering principles to the education of the engineer and to the functioning of engineering in the transition to the new age.

Fundamental developments cannot be limited in their effects to any isolated geographic area but must lead to a world viewpoint. Any approach to such a viewpoint must necessarily be of a tentative nature, but a framework in harmony with universal concepts will have some elements of usefulness. Such a framework is presented.

Changes of a gigantic magnitude are anticipated, but when viewed in their natural perspective they become merely the transition of the human race from childhood to adolescence, and for these changes nature has provided ample facilities and mechanisms.

Bringing about the transition into the new age is a task in which all individuals must participate, and each man must be his own Messiah, all in harmony, however, expressing the basic cosmic pattern. A stupendous task and a glorious fulfillment paint the panorama of the immediate future with a picture of extremely interesting possibilities.

No engineer, or engineering organization, was consulted concerning the purpose of this book, or its contents. The entire responsibility for the views expressed rests upon the author.

John J. O'Neill

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PART ONE

WHAT THE UNIVERSE OFFERS

1. PARTNERSHIP IN THE COSMOS

MAN, in his individual physical experiences, is a prisoner for life between the barriers of birth and death, and is confined for life on a planet known as the earth. With this earth he can do what he will. What he has done is history. What he can do to make his terrestrial home a better place to live in with the enormously expanded facilities placed at his command is the story unfolded in the following pages.

This world to which we are so intimately linked is a part of the cosmos. If we are going to do a really big job in world improvement it is well to get acquainted with our terrestrial sphere. There is just one right way to do a big job and that is to use engineering techniques: straight thinking, sound planning, efficient methods, a set goal attained in the shortest possible time, with a minimum of cost and yielding maximum benefits.

The cosmos, of which our world is a part, is the biggest engineering job in the universe—it is the universe, and is more self-contained than an egg. And it is possible that there may be much in common between an egg and the universe, for the universe too is in the process of hatching into a higher plane of evolvement.

If we are going to do an engineering job on building a new age and a new world, it would be well to get firmly fixed in our minds the idea that it is a big one, and it will be necessary to proceed in the way an engineer would—by getting thoroughly acquainted with the site on which the construction work will be done, and with conditions in the neighborhood which will influence the planning, the building operations, and the use of the completed structure. The site upon which we are going to build is the

earth, and its neighborhood is the universe. It is, perhaps, of even greater importance to the engineer to ascertain something about the people he is dealing with. The people, in this case, will comprise the human race and in particular that portion of it in the United States upon whom there has descended a responsibility for world leadership.

To this end we will make a reconnoitering trip around the cosmos in which our universe is located, find out what is going on there and what conditions and resources exist which may be useful in our world-rebuilding task. Then we will make a survey of the earth and find out what possibilities it offers and what handicaps are hidden in it. Likewise we will get acquainted with the human race, find out what kind of a fellow the human being is, if he is honest, reliable, healthy, financially responsible, has a reputation for fair dealing in the past, and is competent to handle the proposed project when completed. The results of these surveys will be presented in succeeding chapters.

When the engineer has made his surveys and assembled his data he seeks the clearest and most definite statement of the problem he is called on to solve and proposes one, or a group, of possible solutions. He then proceeds to check past performances to ascertain if, and where, any of the solutions were used under similar situations, and with what success. The result usually enables him to concentrate on a single solution as most applicable to his task. He will, in addition, make a survey of current scientific developments to ascertain if any of them may be used in his plans.

In applying this approach to our problem we will make a survey of man's past efforts to set up civilizations and ascertain what happened to them and, if possible, why. This enables us to examine, with a constructively critical eye, the existing situation, to draw up a statement of assets and liabilities and ascertain what we may salvage for the new construction. Man has had some very interesting experiences in building up his various civilizations and we have inherited some mighty valuable material. He

made, too, some valuable mistakes, the benefits of which should not be disregarded.

In our task of engineering a new age we will inevitably find a new concept furnishes the most desirable solution. The engineers, therefore, must first be sold the idea of the new plan and for the next step, the operators who take over the control must likewise lift themselves to a new technical and cultural level. The engineers are not the technicians alone but all members of society participate.

There is one basic idea that man has not tried heretofore and that is to take the cosmos into partnership with his scheme of operations. If he adopts the plan he will find that he has culturally, spiritually, and dynamically refinanced civilization and is set to derive undreamed of profits from the new situation. As a project it is basically sound in every particular.

The new partner is a tough customer and a stern disciplinarian but brings unlimited wealth of resources to our civilization-business. Best of all, he brings complete knowledge of all trade secrets of the universe and can initiate the entire working staff of the civilization-organization into the ceremonies in the inner sanctum where are kept the blueprints which tell what it is all about, where we are going, why, and how.

We have been getting along without this valuable partner in the past. As a matter of fact a great number of our best citizens have quietly ganged up on him and waged a trade war against him on the grounds that they did not like his business methods and objected to his interference with their running their business as they saw fit. They didn't accept the universe and were opposed to the cosmos. Their business, of course, did not grow as big as they had hoped nor pay the dividends they thought their efforts earned; they had to battle with each other continually in order to keep going, and failures were common, but they believed in personal liberty and they were not going to let any cosmos interfere with their right to run their affairs for their own advantage.

Pretty soon a group of practical fellows came along—called themselves scientists. They picked up a lot of information about things that could be usefully applied to making better mousetraps and then a host of other items that could be manufactured and sold at a good profit. They taught the engineers how to make better buildings, trains, bridges, ships, and machines that made the gadgets, and those increased production, reduced labor requirements, and lowered costs. And the beauty of the situation was that the scientists did not interfere with business. They continued to produce their ideas and business expanded as never before. They became indispensable; the entire business world was entirely dependent upon their ideas, the entire financial structure found itself built throughout upon the work of the scientists. The scientists were the most successful group in our civilization. How did they become so? Then the truth came out—they were in league with the cosmos.

Thus stands the situation, science, the business structure, the financial structure, engineering, all prospering in partnership with the cosmos, but retaining allegiance to the Independent Order of Chaos. This, in the very nature of things, must be a transitory state though perhaps an unavoidable one in the course of progress. It is not always clear, however, how the next step shall be taken toward establishing a universal partnership with the cosmos. That is the purpose of this volume. It presents a viewpoint which should aid in extending to all human activities the basic elements of progress which have enabled science, and engineering based on it, to achieve unparalleled success.

Since engineering in its broadest sense is the practical application of science to human welfare, the engineering approach has been adopted. Engineering itself, with a dual loyalty however, is part of the problem.

Like all other professional and intellectual disciplines, engineering is passing through a growth stage leading to maturity. It is like a youth with a strong, fully developed body and keen mind who has been doing a man's work for a long time but has

never been given a voice in the family councils. Engineering has hitherto not manifested a social consciousness nor assumed a social responsibility for its operations. It will, henceforth, find it cannot avoid assuming such social responsibility but in return will be granted greater freedoms. Responsibilities, however, cannot be taken over by those who are not prepared to carry the burdens they involve. Immediate preparation for developing a social consciousness and assuming a social responsibility for its operations is the major and primary task facing the engineering profession today. Its stockpile of technical knowledge is adequate to enable it to start any project and will grow with use.

Who is the master at whose feet the budding and full-blown engineers may sit that they may achieve the wisdom out of which the social consciousness may develop? There is no imperator who can hand down a decalogue of commandments for the engineering profession, or any other profession or intellectual discipline. It is something that must be evolved from within. Its growth can start only after a process of cross-fertilization in which the pattern of progress achieved in all other fields is made a part of the foundations of engineering.

Progress in the engineering profession must itself be engineered. When engineering takes unto itself a social consciousness and social responsibilities it becomes a much larger entity and a more complex one. The old structure, sound as it is, becomes inadequate not only in size but also in design. What engineering does to engineer its transition into the new era of social consciousness may well become the blueprint for engineering the whole human race into the new era. One needs to be endowed with only a medium amount of optimism, imagination, and clairvoyant insight to visualize a much finer structure of civilization than exists today. Civilization is a living thing with internal powers of growth, but this growth must be engineered.

Civilization is the body within which the human race lives; we can shape it as we will. Shaping the new civilization will require engineers with new viewpoints, deeper insights, broader

foundations, and farther horizons. The new engineering will have what its component engineers bring to it.

Engineers will not be the only factor shaping the new civilization. All men will contribute to it, for all focal points of cultural activity will be interconnected, all making contributions to other centers and all receiving balancing contributions so that any development in a particular field will contain factors in harmony with all other fields. We do not now have an engineered civilization. If we don't engineer that job very soon, we may have to do a salvaging job. We won't engineer our civilization, however, until engineers know more about human beings and other subjects not now found in their standard handbooks.

Man himself is the most magnificently engineered job in existence. The human body is a masterpiece of form, function, and efficiency, magnificent in design, awe inspiring in its simplicities and intricacies of operation, and supreme as an integrated conception of interdependent and co-operating factors. It is the work of the Master Engineer. Here is the Master, at whose feet the budding and the full-blown engineer may sit to learn the wisdom that will bring a social consciousness to engineering. The source is within.

2. THE MASTER DESIGNER

IN THE heavens we find an engineering job whose grandeur staggers our ability to comprehend. To those with insufficient eyes the heavens may appear to be the work of an erratic illumination engineer, but individuals with such inadequate vision would see "the light that shines in woman's eyes" but wouldn't see the woman.

The comprehending eye sees each star not only as a scintillating point of light but as a living thing, a vital, pulsating organism. It is not just a mass of molten material but a growing, progressing structure with an internal and external architecture, circulating systems, digestive systems in which nutrient material is absorbed from the environment, reproductive systems in which atoms are formed, power systems in which energy is created, transmission systems in which energy is distributed without wires, and a host of other characteristics with, perhaps, the most important still beyond our comprehension.

It is a beautiful piece of engineering to build a star upon nothing, to hang a sun in space, to cause it to rest on a distant infinity supported by intangible towers of imponderable space, infinitely rigid but of unlimited elasticity, so imperceptible and impalpable that other stars may float their gigantic masses through them with all the freedom of a flying beam of light.

Our moon, which floats so majestically across the evening sky, is taken very much for granted but it presents some interesting aspects. From the terrestrial point of view, the moon, not as big as a dime at arm's length, is supported by, and runs on, an invisible trestle above and around the earth. From the lunar point of view it is bound to the earth by an invisible bar. From an external viewpoint, the two bodies—the earth with a mass

eighty-one times as great as the moon—are linked by an invisible span. The moon has a mass of 72.5 billion billion tons and the earth, 5.9 million billion billion tons. It would require a very substantial steel structure to link these two bodies with either compressional or tensile vectors operating. The moon's motion, which would take it off on a tangent if unopposed, would create large tensile forces on the restraining linkage, while the gravitational attraction between the two bodies, if operating alone, would produce an equally great compressional strain on the linkage. The celestial engineer contrived such a clever linkage and nice balancing of forces that he was able to eliminate all material from the span that bridges them. It requires, nevertheless, a bit of give and take on the part of both earth and moon and a mutual base of operations not centered in either to permit the necessary flexibility in functioning. Here purpose was achieved without mechanisms—the goal of all planning.

It is extremely improbable that any firm of terrestrial engineers will ever be called on to supply the earth with another moon but, if it should happen, it might be well to know that the material for constructing a moon would be equal to that which would be required in building 2 million billion Hoover Dams or Great Pyramids. The sun has a mass 2.7 million times as great as that of the moon. Building a sun would be a really large contract. To build the Milky Way galaxy would call for about 2 billion suns, and there are at least that many such galaxies distributed throughout space. Building the universe involved the handling of a lot of material.

With matter and energy we feel right at home. We have done a lot of experimenting, observing, thinking, and mathematizing about the nature of matter and the fundamental thought arrived at is that matter is composed of particles, simple and compound, in a variety of combinations; and a particle, in its simplest state, consists of energy crystallized in a pattern which manifests the properties we associate with matter.

The atom is usually described as a miniature solar system with a nucleus comparable to the sun and a system of electrons comparable to, and moving in orbits like, the planets moving around the sun. If real accuracy is required, the description is modified because experiments demonstrate that the electrons in the atom do not act like discrete particles resembling planets but instead there exists a fuzzy shell around the nucleus in which an amount of energy, equal to the mass of the electron, is in a state of activity which gives us the impression of rotation. There is such a concentric shell for each electron. The various shells exist at definite distances from the nucleus, the series of distances being proportional to the series of arithmetical numbers. We run into similar difficulties in describing the nucleus. It cannot be supplied with a nice, smooth, shiny surface and a size of definite dimension. It becomes a throbbing ball of energy with a diminishing concentration as the distance from a central point increases. Its surface dissolves into a fuzzy sphere occupied by something resembling a stationary wave that forms a steeper energy potential at that point than would prevail if there were a smooth, outwardly decreasing distribution of its energy. Within there appears to be an array of similar structures, or a framework for them, some occupied by energy and others not, with the possibility of energy jumping from point to point, or from level to level, just as does the energy content of the electron shells, which jumps from one distance to another as if there were grooves in space.

The atom reduces to something resembling a wave pattern filled with energy, and the pattern may be just a manifestation of energy. Allowance must be made for the converse being equally true, that energy may be merely a manifestation of the pattern, with the pattern possessing more dynamic properties than we now associate with so abstract an entity. The solar system exhibits something resembling this wave-pattern structure as is indicated by the fact that the distances of the planets fit into a neat, mathematical expression. Our local universe of stars, the Milky Way galaxy, also has an interesting structure—a densely

populated nucleus surrounded by a disk of stars and within a sphere of stars.

What is the energy we have been discussing? A practical person might toss off the reply: "Energy is something that an erg is full of." Somewhat more specific but not much more enlightening is the oft quoted definition of James Clerk Maxwell: "Energy is the capacity for doing work," and, "That which in all natural phenomena is continually passing from one body to another." It has been more specifically described as the product of mass and velocity, or of charge and potential, and in other ways, but in none of the available definitions is the nature of energy described. We just don't know what energy is. A lecturer appearing before a philosophic group was heckled by the audience for a more specific reply to the question, "What is energy?" He blurted out the spontaneous reply: "You tell me what God is and I'll tell you what energy is. I am unable to make a distinction."

This leads to the picture of the process by which the present state of the cosmos was brought into existence, according to the most satisfactory theory available, that of the Abbé Lemaître, the Belgian scientist. He holds that the universe is cyclic: At one point in the cycle, all of the energy is concentrated in a single atom which divides into daughter-atoms in innumerable successive steps, each emitting radiation, until there is a vast expanded cloud of particles and of the atoms as we know them which then condense into planets, stars, and galaxies, after which a compression phase starts in which the universe contracts until it is again reduced to a single atom, energy being conserved in the process.

The original atom of a creative cycle presents an interesting situation. All of the energy in existence was crystallized into a single atom of unknown dimension. It is not easy to establish a metric under such conditions. Any dimension would be of infinite extent. None of the standards that we use in our present modes of thinking were in existence. If we try to think of it as

extremely small or as extremely large there is no way of distinguishing either from infinity and a clever wordster might equate the situation to zero. At any rate, according to postulate, there existed energy and a pattern in which it was organized or crystallized.

In this situation (the following is not included in the Abbé Lemaître's theory), we make a close approach to that state which theologians describe as "The Godhead." Here was nothing to subvert perfection; here was the source of all power crystallized into a pattern which makes the closest approach to expressing the nature of the Godhead. Into the pattern was written, in its nature, all possibilities within its purpose and the purpose was made manifest in the events which flowed from it.

When the original atom of perfection divided into two daughter-atoms, each inherited the original pattern fully expressed in its diminished amount of energy, and the quantum of radiation emitted likewise carried the pattern fully expressed. So through each step of the dividing process, each split-off portion carried the original pattern until the division reached the stage in which what we call elementary particles appeared and they, despite their relatively small portion of energy, carried the pattern of the original atom in its entirety.

As the particles united to form atoms the particles merged, each atom expressing the full pattern, so likewise as the larger aggregates were formed, solar systems, galaxies, and galaxies of galaxies, each expressing the full pattern. All things composed of atoms express the pattern, and in the pattern phase are not subordinate to either time or dimension, as was the case with the original atom and its pattern.

Every human being is composed of atoms, and is fashioned in the totality of his existence, on the pattern. There are pattern phases of him that are in complete correspondence with the original pattern, and in the secondary pattern-phase, expressed in his material existence, form and function seek to harmonize to a maximum degree with the original pattern.

Through his pattern every human being is linked directly with every other atom in the cosmos, every other sun, every other human being. It is this pattern which makes the universe a cosmos for without it only chaos would exist. There are social and economic implications to this cosmic relationship of man to man and man to his universe, concerning which more will be said in later chapters.

We shall return for a while to the cosmos engineering project and give a little thought to one of the mass production projects which that involved in connection with the creation of matter. We live in a hydrogen universe. Of all the matter throughout the cosmos, more than 99.99 per cent of it is in the form of hydrogen atoms, the largest portion of it invisible and dissociated into protons and electrons. In one pound of hydrogen there are 273 million billion billion atoms. Each of these atoms consists of a small amount of energy crystallized into a definite pattern which is not at all static but vibrant and full of complexities, which indicates that as a manufactured product the specifications were far from simple. It has but two apparent parts, a central proton and an electron shell around it. The proton weighs 1,837 times as much as the electron. Even the light electron is not a simple structure. Its electrical charge should cause it to fly apart, but this does not happen so it contains something that prevents the explosion. This is equally true of the proton. The complete atom is full of resonances so that it can tune in more energy states than a radio receiver can bring in broadcasting band programs. The atom is so small that 250 million of them laid side by side would cover a line one inch long. The earth has a diameter of about 500 million inches. If we take the diameter of a watch as two inches, we could place 250 million watches side by side on the diameter of the earth. This is exactly the number of atoms on the inch line, so an atom compares in size with a watch as a watch compares in size with the earth. The proton is very much smaller than the atom; it would be possible to lay 100,000 on the diameter of the atom.

Keep in mind that it takes more than 273 million million million million of these tiny complicated structures to weigh a pound; that our sun weighs 4,000 trillion trillion trillion pounds; that there are about 2 billion stars like it in our Milky Way and an uncounted number of similar galaxies throughout space, and that the amount of hydrogen in space is from one hundred to one hundred thousand times as great in amount as the hydrogen in the stars—then an idea is gained as to the magnitude of the atom manufacturing job which was required to supply the cosmos with its hydrogen.

The chief, perhaps only, ingredient used in the manufacture of these atoms was energy. Each hydrogen atom required only 0.0015 erg (the erg is the energy unit), or 666 atoms from each erg utilized. The amount of energy flowing through a 100-watt lamp in one second could be transformed into 660 billion atoms. This last number, however, is very small compared to the number of hydrogen atoms in a pound. One kilowatt hour would yield nearly 24,000 million million but this is less than one ten-billionth of a pound. The energy in a pound of hydrogen atoms, if purchased at the rate of one cent per kilowatt hour, which is a low rate for power as we now produce it, would cost about $115,000,000.

Our sun, at this rate, represents an investment in hydrogen atoms (its principal constituent), at the cost of raw materials alone, of 500 billion billion billion billion dollars. It is, in one sense, a heavy, but, in another sense, a light investment. It is the chief item of our resources in the list of assets of the solar system account. This power-house is consuming itself at the rate of 4 million tons per second and transforming this amount of matter into energy. The value of the energy produced per year, at a value of one cent per kilowatt hour, is 27 million billion billion dollars. It has been operating for more than 2 billion years, perhaps at a higher rate in the past than at present, and it can, probably, maintain the present rate for another 100 billion years. At the end of this period, it will have returned in the value

of energy produced nearly the full amount of the investment. This is the power plant of the solar system.

There are nine planets in the system. If the cost is divided equally among all the planets the earth's share of the cost of maintaining the sun is 3 million billion billion dollars a year. It seems at first glance as if this cost is rather high and, on closer examination, this suspicion is confirmed. This amount, added to the war debt, would make our financial burdens heavy to the point at which they would become a really serious matter. On second thought, however, the problem is not so serious as it seems because nature has never sent the earth a bill for its share of the sun's radiated energy.

As a matter of fact the earth does not receive one-ninth of the energy radiated by the sun; it receives only two-billionths part, so the earth's bill for solar energy received is nearer 10 million billion dollars, which is a great reduction. This sum provides solar service to approximately 300 million square miles for a whole year, or less than 1 million dollars per day per square mile. The cost to a man with his home on a suburban plot 100 x 100 feet would be $300 per day. This cost is rather high and suggests the goal at which post-war taxes are aiming. In fact, if nature insisted on charging at this rate for sunlight and heat we would have to stop contracting for solar service, plan to live in a dark age, and join the Eskimos.

Fortunately scientific progress has saved the situation. Atomic energy has been released. The sun uses atomic energy processes to produce her energy. The costs given above were based on the cost of energy as produced on the earth by burning coal. A pound of coal produces, in an average power-house, 1.43 kilowatt hours; one pound of hydrogen atoms converted into energy produces 11.35 billion kilowatt hours. Since nature has no overhead charges, no need for amortization, and operates without labor costs, it can be assumed that costs will be reduced in proportion to the increased rate of production, or to about one ten-billionth of the previous figures.

At this atomic energy rate, the cost of solar service per square mile of surface of the earth per year drops from 300 million dollars to 3 cents, and the cost of solar service to the suburban plot or a city apartment house drops to about 1 cent for 300 thousand years. Incidentally, by going over to an atomic energy cost basis, the cost of manufacturing the hydrogen necessary for making one sun is reduced to 5 billion billion billion dollars. This is still a heavy cost for a light project and it is fortunate that a solar system can get along with only one sun.

It was mentioned that the earth intercepts only one two-billionth part of the sun's radiation. The total amount intercepted by all the planets combined would not increase this fraction to an appreciable amount. Don't think that the vast remainder is wasted by being poured into empty space where it performs no useful service. The Master Designer is too good an engineer to be guilty of any such wastefulness and inefficiency. He knows His elements and He keeps them all busily engaged in useful services. Masterhood confers on Him the ability and the responsibility to achieve complete solutions to all problems. He doesn't waste sunshine.

Surrounding the sun, far out to the orbit of Pluto and beyond, and likewise surrounding practically all stars, is a concentrated atmosphere of hydrogen. It can be spoken of as concentrated in astronomical parlance but in terms of the gases with which the terrestrial engineers work, it is in a highly evacuated state. Close to the sun, its density is about 10 million million atoms per cubic centimeter; around the orbit of Jupiter, it is reduced to 1 million; and, at Pluto's orbit, about 1,000.

The average amount of hydrogen in a cubic centimeter is very small but the number of cubic centimeters in the solar system (radius, 6 billion kilometers) is tremendously large and the total mass of hydrogen, as indicated by present calculations, is equal to about 300 times the mass of the sun. The amount indicated by spectroscopic observation is very much smaller, but investigation of the earth's and the sun's atmosphere by

radio waves, and by study of the manner in which comets become luminous as they approach the sun, indicate that vastly greater amounts of hydrogen exist in dissociated form in which it could not be detected by the spectroscope. The normal two-atom molecules of hydrogen are separated by ultraviolet radiation and more powerful radiation separates the electron from the proton, producing an electrical atmosphere which, in the earth's ionosphere, reflects radio waves below a certain frequency and makes worldwide radio communication possible.

It takes a lot of energy to separate the atoms in a molecule and a great deal more energy to pull the electrons out of the atoms. The sun's radiation which seems to be wasted by shining out into empty space is being absorbed principally by the vast amounts of surrounding hydrogen gas where it is put to work dissociating molecules and atoms and storing in them the energy required to dissociate them. The amount of energy stored in the vastly extended hydrogen atmosphere of the sun is tremendously great. Its temperature is in excess of 2,000 degrees. This heat is in a latent form. Because the electrons are drawn out of the atoms, the atoms cannot emit radiation nor absorb any. The only way they can cool down is to condense on solid matter. This is what happens in comets, causing them to become luminous as they enter a region between Jupiter and Mars where the dissociated hydrogen density becomes sufficiently great. The hydrogen gives up its energy to the solid particles in the comet, raising their temperature, and the same phenomenon takes place in the upper regions of our own atmosphere in the case of shooting stars.

The sun is undoubtedly using this vast amount of energy stored in her invisible atmosphere in ways which we do not now suspect. It is comparable to stored fat in living organisms, or to glycogen, the body's fuel, stored in the liver.

The nucleus of the sun, the part we see, feeds itself on hydrogen from its surrounding atmosphere as the fuel to keep its atomic energy processes in operation. These processes have a

highly biological aspect. A carbon atom acts as a mother substance. It takes in as nourishment successive hydrogen atoms. When it takes in the fourth atom it gives birth to a helium atom into which it has transformed the four hydrogen atoms. The one helium atom has slightly less mass than the four hydrogen atoms. The difference was transformed into energy—radiation—in the gestation process and used to maintain the sun in its incandescent state, which is necessary for the continuation of this process for building the lighter elements.

Conditions in the sun provide a suitable environment for the synthesis of the lighter weight atoms. It is possible that the conditions in the cooler outer atmosphere of the sun provide a more suitable environment for the synthesis of the heavier elements which may rain back on the sun in the form of meteoric particles, and which under suitable conditions may form clouds and as such, in the form of comets, shoot back and forth to and from the sun before they finally disintegrate and fall into it. Planets may be formed in the quiet nodes of stationary wave-patterns surrounding the sun.

This electrical atmosphere around the sun, still subject to early pioneering investigation, presents almost fantastic possibilities for strange phenomena which would make the sun a living, pulsing, growing thing, with definite biological aspects. We may some day learn how to draw energy from this solar storage battery, and some day it may spark to the earth with cataclysmic effects. It has very definite engineering aspects. It may be the mechanism we shall use in controlling climate and the earth's temperature. It contains some obvious possibilities as a means for transforming our upper atmosphere into a giant "neon" lamp globe with which to illuminate the earth at night. It may be a source of energy which can be directly translated into electric currents.

The observations in this chapter are offered, not as a cultural contribution which may have some usefulness in a dim and distant future, but because they contribute something of im-

mediate value to the equipment of the engineer and the populations with which he will work, in the new age which is dawning. The intent is to dissolve the mental barriers which have isolated groups from each other and have prevented man from realizing the intimate linkage that exists between him and his cosmos.

In a cosmos everything is an expression of a fundamental pattern and every activity in every field has its roots in this primary pattern, each field containing a prototype of it. If for any reason a portion of the pattern is obscured in one field, it can be discerned in another. The viewpoint is important that nothing can be done in one field without having its effect in every other field, and planning is not complete unless provision is made for all effects produced. This aspect of Nature is well abbreviated in the lines of the poet, Fredericka Blankner*:

> The universe is strung upon a single thread—
> Tug at an atom and a star falls on your head.

* *All My Youth,* Brentano's, New York.

3. THE PULSING BALL WE CALL THE EARTH

MAN IS engaged in decorating, sometimes in desecrating, but always in changing, the earth, to some extent, for a particular purpose, usually of a highly specific nature and for a highly specialized reason. He will, in the future, continue these operations but his purposes will change in a fundamental way and the scale upon which projects will be cast, greatly enlarged.

The human race will be much wealthier tomorrow than it is today. There is just one form of wealth which humanity can utilize, and that is energy. There is just one fundamental product or activity in which we can engage, and that is changing the form or relationship of things. Changing the form of things consumes energy. This is true whether the thing created is a new configuration of thought, a painting on the artist's easel, an electric motor, a filing cabinet, a ship, a bridge across the Golden Gate, or an Empire State Building. All of these things are merely products of the earth transformed better to satisfy man's needs, cater to his desires, or aid his progress to a higher destiny.

The extent to which we have been able to operate on the earth has been limited by the amount of energy available to us. In the atomic age now with us, the energy-wealth of the human race will have been increased at least two million fold as a first step, later increased to ten billion fold as compared to the carbon-energy age now flickering to a turbulent close.

We should keep in mind, as we enter the atomic age, that we must visualize the earth as supplied with a new and vastly more powerful agency for carrying on her operations. This agency has,

of course, been operating ever since the dawn of creation but we did not know about it. Chemical and compressional heat provided the energy to activate changes according to our theories. Today we see nuclear energy sources providing the forces to activate terrestrial changes. We recall that, with equal masses involved, the energy from mass transformation is to the energy from chemical reactions as 11 billion to 1. The small amount of energy from chemical processes necessitated the long time scale of geological processes. Hundreds of millions of years were allowed for a mountain-raising process. This has led to a belief that the earth has been, and will so remain, unchanged in any significant way for millions of years. We may have to change the geological time scale by a very large factor. It would be wise to visualize a possibility that a mountain range could be raised in a year as well as in 100 million years.

Heat accumulations could lift not only mountain ranges but also continents. There is a lot of uranium, thorium (perhaps some plutonium), and potassium widely, almost uniformly, distributed throughout the outer rocky mantle of the earth. We have seen how chain reactions take place in nuclear activity and there is no reason why they would not operate on a slow motion scale as well as an extremely fast one. With such operations under way the surfaces of continents could rise and fall like the billowing of a lazy ocean. Even if a section of a continent were raised mountain high, not in a year but in the course of a century or even a thousand years, the rate would nevertheless be quite rapid, and significant changes could be observed in short periods.

It is going to be necessary to have terrestrial or earth engineers whose business it will be to keep the earth under close observation, surface and subsurface, to detect earliest signs of activity and, if possible, to control them. We may find it desirable to develop atomic energy processes which will be the reverse of these which now hold our interest. We are now interested in processes that release tremendous amounts of energy. Our future welfare may make it highly desirable that we work out processes

capable of absorbing tremendous amounts of energy at very rapid rates. There are such nuclear processes. They may be needed as protective mechanisms.

Our earth has been quiescent in the inhabited portions that have left records for about two thousand years. Concerning the earlier periods there is considerable uncertainty. The dinosaurs disappeared suddenly from the earth. We say they grew so large they became ill-adapted to conditions. This may be true but it does not explain the hundreds of other species, well adapted to their environment, that disappeared at the same time. The camel and the mammoth and many other species disappeared with equal suddenness at a much more recent date from this continent. Cataclysmic changes are a much more likely explanation. If there is any possibility that man may disappear in continental units under such circumstances, it would be well to circumvent the situation instead of fooling ourselves with a false sense of security.

There is another aspect to the terrestrial situation which merits attention. We have bored many deep holes in the continental land masses and find that the deeper we go the hotter the rocks get. The rate of increase varies with location. We have not reached very great depths. One oil well hit the three mile mark. We have reasoned: A 50 degree rise in one mile means a 500 degree rise in ten miles, 50,000 degrees in 1,000 miles; 200,000 degrees in 4,000 miles or at the center of the earth! But we have never gone below three miles, so extrapolation to 4,000 miles is rather an unsafe procedure. We have studied seismic waves which have traveled through the deeper parts of the earth and these indicate that conditions exist in a large core region which prevent certain types of waves from being transmitted. A hot plastic core would explain the situation but may not be the only explanation.

There is reason for keeping an open mind in the matter. We have, in recent years, made world-wide surveys of the ocean bottom and we find the temperature of the water in contact

with the bed of the ocean ranges from O° Centigrade to 2° Centigrade, or in other words, the water there is right on the edge of freezing! This holds true for all parts of all oceans. Investigators * calculate that the heat gains and heat losses of the oceans through all surface phenomena balance each other. The ocean, then, should be in thermal equilibrium with the ocean bed, which indicates a slightly above-zero temperature for the latter. The amount of heat transmitted to the ocean from the earth is estimated at 50 to 80 gram calories per square centimeter per year, an extremely small amount indicating the ocean bed is very cold.

We have here a very interesting situation: those portions of the earth's crust which have not been elevated to become continental land masses have a temperature of O° whereas the continental masses, when penetrated a short distance below their surface, have much higher temperatures. The question arises: Does the high temperature of the land masses have any causal connection with their being lifted high above the ocean bed? In a terrestrial scale sense the ocean is only a very thin skim of water with relatively small mass compared to the mass of the earth; it is really just a wet spot on the globe which the wipe of a terrestrial hand could flick off into space. It probably has, therefore, no appreciable effect on the temperature of the earth as a whole. If two thirds of the earth's solid surface has a temperature of O° Centigrade, then it can be asked if it is not probable that the interior of the earth is very cold with temperatures going down perhaps to absolute zero (— 273 degrees)?

We now have two opposing possibilities—an earth with a hot interior and an earth with a cold interior. Which possibility matches reality? The terrestrial engineers' patrol has a nice task ahead of it trying to solve this problem. The cold earth theory is tenable if it is assumed that atomic energy activities heated relatively thin portions of the top crust, not deeper than the depth of 50 to 100 miles, and the expansion caused them to be

* *The Oceans,* Sverdrup, Johnson, and Fleming. Prentice-Hall, New York.

lifted into what we call continents. The cold mass of the earth would act as a reservoir into which the heat produced at a rapid rate by the atomic energy processes could be absorbed at a slower rate and eventually cool the heated mass, causing it to contract until the top were below sea level. There are some practical problems in long range planning which would be affected by a solution of the hot-cold earth problem.

Not long ago a movement was started to dig the deepest possible hole in the earth. It was to be an exploratory project with a primary purpose of securing knowledge of subsurface conditions but with arrangements to be made to exploit valuable minerals encountered. The first question to come up was: Where is this hole to be drilled? That is a really fascinating problem for the terrestrial engineering corps. In the author's report, not one but fourteen desirable sites were indicated with excellent and equally good reasons in favor of each location. All were within, or close to, the borders of the United States. There are even more interesting locations in other parts of the earth.

If holes were drilled in some parts of Mexico, hot spots might be encountered. The new volcano, Paracutin, which broke through the crust a few years ago, occupies a site marked by an unusually warm and productive field during preceding years. Two decades ago Mount Lassen, in northern California, let loose an eruption that was of major magnitude. A volcanic eruption in one part of the earth is frequently the forerunner of a series of such outbreaks in far distant areas.

Our earth is not the dead, inert, hard thing it seems to be when viewed at close range. Viewed in a larger aspect it is a soft, pulsating thing. Thanks to the studies of scientists working with what is known as the scale theory, properties of substances have one aspect on a small scale but an entirely different aspect on a large scale. For example, a slab of steel, square in area, measuring ten feet along its edge and an inch thick, could be supported at its corners and not exhibit appreciable deformation. The sag would be measured in thousandths of an inch.

Suppose one could cut a nice flat section of the earth, twenty miles thick, approximating a rectangle and about the area of the United States, and a superman with fingers about the size of Lake Michigan were to undertake to lift this slab. Would it lift like the slab from a glass top desk? No, it would respond quite differently. It would lift like a sheet of freshly rolled, unbaked pie crust dough, or like a piece of silk; the material would drape through the fingers. The rigidity of a granite lintel spanning a three-foot door is something vastly different from the rigidity of a slab of granite with a 500-mile span. It is quite probable that if a fist measuring a thousand miles across should hit the earth a good healthy wallop right in the middle of a continent the earth would not shatter—it would spatter.

In ancient Egypt, the high priests were engineers. Through accumulated knowledge they knew the Nile valley undulated. They knew it rose and sank with a slow, sinuous, and irregular motion. The changes affected the flood supplies of water upon which the prosperity of the people (and the royal revenues) depended, and created the need for economic and social restraints if the flood situation were beyond their controls. Evidences of earlier civilization have been found buried fifteen and more feet, not only below the delta region but far up the river valley. There is a great split through eastern Africa, extending from its southern tip into central Asia. It may have been active a few centuries before the opening of the Grecian era. During the first century of the Christian era there was a cave high on the beach east of the Nile delta in which the early Christians held their religious services. The top of the entrance to that cave is now three feet under water. In Sicily temples erected in the days of Magna Graecia can be seen entirely submerged under the waters of the Mediterranean.

Although no such plan has ever been discussed, it is reasonable to assume that we desire to establish a civilization that will last for, let us say conservatively, ten thousand years although it is really a mark of intellectual cowardice not to plan for one hun-

dred thousand years. If we think of years in the way in which we think of the rotation of an electric motor, which turns over at the rate of nearly thirty-six hundred revolutions per minute, then one hundred thousand revolutions of the earth around the sun is not such a long period, less than half an hour in the life of the solar motor. Long range planning of this type is possible under an engineering approach but not under a political approach. The politician will insist that even a one-thousand-year plan is impracticable because he is sure that no chief executive can be expected to live long enough to see such a plan through to completion.

There are reasonable grounds for assurance that the human race is going to inhabit the earth one hundred years from now, one thousand, ten thousand, and one hundred thousand years from now. We should plan accordingly. There will be changes, plenty of them, and of major magnitudes. Life then will still be an energy manifestation operating through material structures—living and non-living. That provides a reasonably broad basis, and it allows scope for arranging for tremendous changes in shaping not only the earth to man's desires, but, more important, shaping man to man's desires, for there is really ample room for improvement in us.

We have started comparatively long range planning with respect to our river valleys; we have begun to develop their water power possibilities for generating electricity just as the atomic energy age comes in to make hydroelectric power obsolete. There are, however, many redeeming features to our river valley plans. We don't want to overlook Mother Earth when we make long range basic plans.

Take the Mississippi River valley as an example. We have been building some excellent levees to contain the annual floods and have started the job of controlling the tributaries so that within the span of a chief executive's lifetime no congressman's constituents can complain that Ol' Man River is overstepping his bounds. It would be a mean trick if, after this has been ac-

complished, the Great Lakes should become perverse enough to empty themselves into the Gulf of Mexico by way of the Mississippi River instead of into the Gulf of St. Lawrence. It may be news to the citizens of our fair land that nearly all the eastern half of the United States is an island, made so by a quite inconspicuous piece of engineering in which a river was made to run backwards.

The elongated Lake Michigan became very much of a dead-end body of water at the southern extremity where sits Chicago, and it was found desirable to give it some drainage. The Chicago River, a modest bit of creek, drained a mid-section of Cook County and emptied its aqua pura, plus dissolved and suspended contents, into Lake Michigan. The Illinois River had its origin in or close to Cook County and flowed in a southwesterly direction to drain the northwestern half of Illinois and empty into the Mississippi a short distance above St. Louis.

A canal was dug to connect the Chicago and Illinois Rivers and so graded that the Chicago River reversed its flow and, instead of emptying into Lake Michigan, it drains Lake Michigan, flows into the Illinois River, and thence into the Mississippi. The eastern portion of the United States is, therefore, an island bounded on the north by the Great Lakes and St. Lawrence River, on the east by the Atlantic Ocean, on the south by the Gulf of Mexico, and on the west by the Mississippi, Illinois, and Chicago Rivers. An island without a name!

The Great Lakes are tilting. Their northern shores are rising and their southern shores are sinking. The rate of change is small during the period of observation, and the accumulated amount will not be important even by the time a plan has been worked out for reconstructing Europe after destroying it.

If a small change is linear, if it continues at a constant rate, and if the cumulative total over a long practical period does not reach important proportions, making adjustments to it may not be difficult. It is necessary to know, however, that the rate of change is constant. The idea of constant rates belongs to an

earlier era. Major changes by quantum, unit packages suddenly emitted, are more in keeping with present concepts.

The upward movement of the northern part of the Great Lakes Basin is, according to our present way of thinking, caused by the earth's surface in that region springing back to normal after being depressed by the heavy overburden of ice it carried during the glacial period. If this is the case we have a parallel situation in northern Europe which was covered with ice at the same time. But here the rise of the land is not uniform. In the northern part of the Gulf of Bothnia, an arm of the Baltic Sea, the land is rising at the rate of four feet in a century while in regions around southern Denmark and in northern Germany the land is sinking at a slow rate. Perhaps other factors are operating.

Just a few seconds ago in a geological sense, actually more than a century ago, 1812, there was a great upheaval in the mid-region of the Mississippi Valley where it cuts between the Ozarks and the southern end of the Appalachians. A vertical displacement of forty-five feet took place in that disturbance, known as the New Madrid (Missouri) earthquake. Exploration below this region revealed that an even greater displacement took place at some earlier period. Reelfoot Lake, thirty miles long and five miles wide, in western Tennessee, close to, and paralleling, the Mississippi, was created in 1812. This is the second most active earthquake area in the United States, California having a big lead. Each earthquake brings about a relatively minor change but the summation of all changes over a century or two may bring about significant alterations in the landscape affecting drainage areas and the location of basins.

There is no immediate urgency about this problem. It is presented here merely as an effort to break away from a viewpoint that is too local in time with respect to the planet on which we live and to the civilization of which we are a part. The long view may suggest more basic solutions of our problems in which it does not make any difference where the Great Lakes are, in

which direction the Mississippi flows, or whether the Tennessee Valley dams are full or empty.

Suppose the terrestrial engineering corps of a ten-century planning commission were called upon to pass judgment on the desirability of continuing or discontinuing the development of present major city sites such as New York, San Francisco, Chicago, and New Orleans. Would the fact that sections of the coastline in the neighborhood of New York are sinking at the rate of more than a foot in a century encourage further development?

Would the fact that the excellent harbor at San Francisco was produced by a collapse, in the long distant past, of that section of the coast range, that the movement may not be complete, or may be reversed and start lifting or closing the Golden Gate, cause it to receive a ten-century stamp of approval? The east end of Terminal Island at Long Beach is sinking at the rate of six inches a year. Mare Island Navy Yard is also sinking.

Fifteen feet below the level of the Nile delta are the buried foundations of buildings which were once above tidal level. The situation is not different from that in New Orleans today, where we have lifted the river so its top levels are many feet above the levels of the city's streets. The fact that Lake Michigan may wet Chicago's feet has been mentioned, to which may be added the possibility that Cleveland's source of drinking water, Lake Erie, may spill itself into the environs of Euclid Avenue, and a future New Orleans may be built on a higher level, or elsewhere.

Boston, New York, Philadelphia, Baltimore, and Washington all rest on an ancient geological fault line now well stabilized. Shortly after the Pilgrim Fathers got nicely settled throughout New England, nature did a little more settling by shaking the whole region with several severe earthquakes, but the region has been relatively quiet since then, except that a few years ago a section of the Grand Banks, off its coast, dropped about ten feet. These are just some thought provokers as a kind of mental backdrop for long range planners.

Then there is the probability that climate may be variable in-

stead of permanently fixed, as is now generally believed. The climate of the United States is getting warmer to a significant degree. The trend has continued for a century in places for which we have long-time weather records. It may be a cyclic change of short period to be followed by a trend toward colder weather. It is at least equally probable that the trend toward higher temperatures is a very long period movement which would have to be considered by a ten-century planning commission.

That this change results from purely terrestrial conditions is indicated by the fact that the major increase in temperature is confined to the winter periods, the summer temperatures staying within normal range of variation. The dominating factor in our winter weather is the movement down over middle latitudes of great masses of cold air detached from the polar air mass.

It is only in recent years that we have started to accumulate continuous observations of Arctic and near-Arctic weather conditions, so we don't know, from accumulated data, how the temperature is changing there, but the warmer winters of the United States indicate that the air coming from there is continually getting warmer. Stefansson, the Arctic explorer, reports that in thirty years the temperature of the Arctic Ocean has increased three degrees but he is inclined to think this is a short range cyclic phenomenon. The polar ice cap is melting back at a rapid rate from the coast of Greenland and glaciers everywhere are receding. The southern edge of the permafrost, the permanently frozen ground, is moving steadily northward at a relatively rapid rate.

Fossil remains of plants and animals indicate that a subtropical climate once existed in the Arctic. Spitzbergen is underlain by an almost uniformly extended mass of coal formed under tropical conditions. The region may be warming up again. The Arctic Ocean joining Spitzbergen with the Atlantic has been free of ice during the winter weather in recent decades, whereas it was formerly ice bound during the cold season. It is just pos-

sible that the great ice sheet which covered Canada and the northern third of the United States was melted by a relatively recent increasing temperature in the crust of the earth beneath it and may have been originally formed by a cooling of that region. The heating may be continuing and causing an expansion of that portion of the earth's crust and a consequent lifting of that portion of the continent, which may explain, better than the release of ice pressure, the southward tilting of the Great Lakes. Some of the northern Canadian islands have been lifted as much as fifty feet. These are problems with which the geologists are now struggling in applying the new atomic energy viewpoint to geological phenomena. The important factor is the rate at which these changes are taking place. A five-degree increase in the average annual temperature would give most of Canada the average climate that the United States now has. If the climate of the United States is getting dryer as well as warmer, a population shift northward may be found desirable.

With unlimited amounts of energy available from atomic energy processes, and a better knowledge of nature's mechanisms than we now possess we may be able to produce climate to order, or we may even become independent of climate through an increase in knowledge. Our dependence on climate is based on two principal factors: growth of food supply, plants, and animals and a fixed temperature control mechanism within our bodies.

We are dependent on climate because we use as farms and ranges the conditions of soil, water, heat, and sunshine as they occur by chance in nature. It is most fortunate that we were able to do this during the scientific and engineering infancy of the race when it was energy-poor. Now we know how to grow, in nutrient solutions, more luxuriant crops than ever came out of the soil. Our biochemists have partially discovered that plants are much less dependent upon solar radiation than we believed, that they can produce normal growth with much fewer quanta of radiation, used through an enzyme system in the plants, than

were believed to be required under the chlorophyll theory. This means an easier job of growing crops under artificial light. With the cheap, very plentiful supplies of atomic energy we can pump water anywhere without dependence on dams, and supply all the heat desired. Farms will be factories in buildings entirely independent of sunshine, rain, and soil. Land will present a different aspect when a one-acre factory may produce as much food as a 640-acre section of land.

Releasing human beings from climate dependence through internal manipulations is a more difficult task but the solution is within the realm of possibilities.

We are dependent on the earth for all mineral resources. Our utilization of these resources has always been dependent upon the extent to which we could afford to expend energy on them—human or physical—to shape them to useful purposes. Those materials which could be utilized with least expenditure of effort—at least cost—were the ones most commonly used. Nature has used to the least extent in her economy those materials which man has used to the greatest extent—metals. Stone is nature's preference.

Metals are very widely distributed in nature. Because of the necessity for being extremely thrifty in our expenditure of energy we have used only the sources in which metals are highly concentrated. These concentrations were produced by nature through chemical reactions which she operated on a large scale in rather unusual furnaces in subsurface workshops. With ample energy available and means for applying it, and if we are not in too great a hurry to receive returns on efforts invested, we may be able to duplicate nature's processes for concentrating ore bodies from lean rock resources.

The ocean is a source of a great many minerals. Half of the chemical elements can be found in it either in solution or suspension in measurable quantities. It is rich in organic matter, vegetable and animal. If processes could be devised by which all of the material in seawater could be utilized, a cubic mile of

ocean would yield tremendous quantities of fertilizer, food, raw materials for organic synthesis, and even useful amounts of such substances as lithium and uranium, both of which are useful in atomic energy processes. Mining the ocean, practicable on a vast scale, would yield a vast array of useful products.

The atmosphere will become a source of nitrates obtained by much simpler arrangements than any heretofore proposed. The combination of the oxygen and nitrogen will take place through utilization of solar radiation, thus eliminating power costs, an important element in electrical processes, and proving a method simpler than those involving chemical operations. We may fertilize the soil in our food-producing factories with petroleum products instead of using them as fuel; coal products likewise.

If we could develop an enzyme, a chemical process activator, that would fix nitrogen from the air in our lungs and transfer it to the blood stream, and a few other enzymes that would enable us to synthesize the amino acids which the body is not now able to make, we may become free to a great extent from the need for animal products as food sources—and would the vegetarians be happy! Add the enzyme from the plant world which knows how to separate the carbon and oxygen that are in combined form in carbon dioxide and set them free as energy-charged chemicals. It could utilize the carbon dioxide we now exhale in our breath and feed it back to our bodies as free carbon for fuel and free oxygen to support its combustion. Nitrogen, carbon, and oxygen—the principal elements of nutrition would thus be obtained from the air as we breathe it. With a few minerals that we would obtain from our drinking water, we would be independent of other food sources. Hydrogen is a major component of our bodies, but the only part of the hydrogen atom that takes part in chemical reactions is the electron, and electrons are very plentiful in the electric current which may be a clue to a source of supply for this element.

Such a situation would bring about a tremendous change

in our relationship to the earth. We would no longer be dependent upon the soil for our food. The land used for farms and ranches could be released back to nature. We would not have to struggle for "our daily bread," and the time required for the struggle could be utilized for other purposes. The possibility, remote as it may be, is offered as a thought catalyzer, a kind of range-broadener for the mental processes.

Our earth is going to present a far different aspect to tomorrow's civilization. Some of today's most critical problems with respect to it will vanish, to be replaced, perhaps, by new ones equally challenging.

PART TWO

MAN TAKES CONTROL

4. PRIMITIVE WORLD ORGANIZERS

AS WE dig back into time seeking the earliest records in any field we find that the early historians were poets who loved to record events and ideas in broad glowing terms and glittering generalities. Theories, conditions, developments were personalized and dramatized. Everything becomes a bit hazy and nebulous. The precision of statement (which does not at all imply accuracy) and abundance of detail, of which we make a fetish in our modern methods, are totally lacking. Strange names are given to common things, personal attributes are ascribed to them. We feel there was a lack of comprehension on the part of early observers and recorders and they had not attained a broad understanding of nature which we have attained. The specific details that we hope to find are usually missing yet only too frequently, when we find particularized information, we disbelieve the statements. If the theories and observations of our predecessors do not support our present plans and desires that is, of course, considered an entirely satisfactory reason for completely rejecting them as the work of ignorant and incompetent individuals.

If we give a little thought to present-day conditions we may find that our poets are far ahead of our scientists and engineers in grasping the basic concepts of nature and man's accomplishments that are based on them. The course of progress is pioneered by the poets, followed by the philosophers, then the speculative scientists who pave the way for the experimental scientist who opens a thousand paths along prosaic engineering lines and along which business establishments are set up.

Our poets have ever voiced the thoughts which are under-

standable by all men. When we go beyond them we get into specialized fields where the language and thoughts become increasingly incomprehensible. Perhaps there is a very definite advantage for us in the fact that the early historians were poets and generalizers and if we would get into their mood we might discover some really important basic concepts that they are seeking to pass on to us.

We have been taught that the idea of the universe as a cosmos, ruled throughout by order under natural laws and all of its parts in harmony, had its origin in the days of Isaac Newton and Francis Bacon. That attribution is totally without factual basis but is, nevertheless, taught and believed. The theory has been taught continuously throughout the ages. Actually the earliest clear statement of it is found in the writings of Hesiod, the early Greek (eighth century B. C.), who was a combination of theologian, historian, poet, and philosopher. According to him, the first task which the gods were required to handle following creation was the injection of a sense of order into chaos and the creation of harmony among parts. The task was assigned to Eros (whose name was later changed to Cupid, and whom uncomprehending moderns have converted into a sentimental zany).

We still worship Eros. Anyone who today believes in systematization and law and order, worships Eros. The modern statesman who addresses the citizens saying, "We must have law and order in our country," is saying exactly the same thing as an early Greek statesman who said, "In conducting the political affairs of our country we must not neglect to pay all due reverence to the worship of Eros."

When the early Greek myths (and parallel records in other civilizations) tell us that Uranus, the god of the starry firmament, was deposed and succeeded by Cronus, the god of the sun and planets, and he in turn yielded dominance to Zeus, the god of the sun (the name means "the shining heavens"), and that Zeus gave birth to Ge, or Gaea, the goddess of the earth, they are telling us exactly the same story that Kant and Laplace told us in very

recent centuries in their nebular hypothesis, which was believed to be a completely new conception.

When we worship the "Deity" we feel that we are in some very definite way superior to the ancients who worshipped Zeus, yet Zeus is merely the Greek translation of the "Dyaus," the more ancient Vedic sun god. The Roman god Jupiter (equivalent of Zeus) was, in earlier form, Jovispater, and still earlier Djovis, which is the literal Latin translation of Dyaus. Our English word "Deity" is a direct derivation of Dyaus.

Very definitely modern is the myth that Zeus commissioned Vulcan, the god of heat, to fashion the human being out of the substance of Gaea (the earth). If we were forced to boil our modern theories down to as few words and make them interesting and understandable to the greatest degree by the greatest number, we could not improve on that myth.

The human being was Pandora, a female, and was so called because she received gifts from all the gods and goddesses. That is merely the early poet's way of saying exactly what our best biologists say today—that the human being is the product of all natural forces and is directly linked to the entire cosmos.

Pandora was presented as a gift to the gods Epimetheus and Prometheus, who were brothers and who were to father the human race. A very clever psychologist was at work in creating these brothers, Epi and Pro. Their names describe their characteristics: Epimetheus—he who acts first and who thinks (if at all) afterward; and Prometheus, he who always acts with forethought. No modern psychologist could make a division of the human race into two simpler and more accurately descriptive categories—those who think and those who don't; those who live in their bellies and those who live in their brains.

Epimetheus, who didn't think and lived in his belly, thought Pandora was nice, gave her the wolf whistle, and took her to wife. Prometheus had work to do that required thought. One of the big jobs he tackled was to split the head of Zeus with a cleaver and release, to be born full grown, Athene (or Minerva, also

called Mechanites, meaning "the ingenious one"), the goddess of knowledge. This is just the poet's way of saying exactly what our best modern science teachers tell their students—that you must go to nature for your knowledge and you will find it full grown and complete, if you can dig it out.

Prometheus was the first scientist. He studied everything, even the great god Zeus himself. He discovered the secret, and the destiny, of the sun and of Zeus, and with his characteristic forethought refused to reveal it to Zeus. With this power, he was able to force Zeus to accept only a small fraction of the sacrifices he previously required of human beings. This is merely the poet's way of saying that as we increase our knowledge of nature and how to utilize its forces, we make it possible to support ourselves with smaller contributions of effort.

Like the typical scientist, Prometheus carried his work still farther. He took the fire from heaven, the substance of the sun, right out of the body of Zeus himself and carried it down to earth as a gift to the human race. This tells the story of man's conquest of the use of heat, the form in which energy, the activating principle of the cosmos, was made available. It tells also the story of the most modern phase of this development, man's release and use of atomic energy from matter, the process which permits the heavens "to shine with the glory of God" (as the original Biblical versions state).

Prometheus was punished for his act by Zeus. He was chained to a rock, when he assumed human form as a gift bearer, and forced to suffer torments. Perhaps our scientists of today who find themselves enslaved to a situation which they created by making available the uses of energy and knowledge to the Epimethians can understand the predicament of Prometheus.

It can be hoped that the early Greek myth makers were prophets, for according to their story it was Hercules, the first engineer, who released Prometheus from his torments.

Zeus perceived the need of an engineer who could undertake the big jobs required to make the earth, the domain of the great

goddess Gaea, a more suitably habitable place for the human race. He looked over his Pantheon. There wasn't a god in it who measured up to the requirements of the job. There was, of course, Prometheus the scientist, but he had been banished and he couldn't select him because a good executive never admits his mistakes, even when he knows he is wrong.

It was obvious it would be necessary to create a man for the job of chief engineer. First, there was the task of selecting a suitable mother. He had done a pretty good job of creating his goddesses so it was not easy to make a choice. He could go back to Gaea, but no—he wanted someone more specialized. He visited the earth and made a survey of mortals. A process of elimination led him to just one—Alcmene. "There," said Zeus, "is a woman fit to be a goddess!" She had charm, grace, intelligence, and physique. And in addition she was the daughter of Electryon, and the wife of Amphitryon, an aristocrat of Thebes. Just the woman he wanted. And when Zeus wanted something what minor executive would risk opposing him?

Alcmene presented Amphitryon with the lusty infant whom she named Heracles, and everyone was happy, except Hera, the wife of Zeus. When she got one glance at the infant Heracles she was angry clean through. Grabbing the serpent from the staff of the passing Hermes, she threw it into the cradle of the infant who instantly crushed every wiggle out of it in the grasp of his mighty hand. She decreed that he should go through life facing an unending series of the toughest possible tasks.

Heracles grew quickly into a strong, tough, hard-hitting, square-dealing young man; his name was changed to Hercules. He was assigned a famous list of twelve jobs, each of which he carried through to completion in contract time. One of the best known of these jobs was the task of sanitary engineering—cleaning the Augean stables.

Cleaning the Augean stables at Ephyra was a man-size job. The stables were plenty big. There were three thousand stalls, all of them filled with oxen and the necessity for a clean-up. They

had not been forked or sprayed for thirty years. The stables were on the estates of King Augeas, who ruled the kingdom of Elis on the northwestern corner of the Peloponnesian Peninsula in Greece. The king hired the job out to Hercules on a ten per cent basis, that is, Hercules would receive one-tenth of the cattle in the stables, but there was a "time-is-the-essence" clause in the contract—the job had to be completed in one day.

Hercules took in the whole landscape and situation at a single glance, in typical engineer fashion. He noted that the stables were close to the Alpheus River, and a little on the down grade from one point. Taking his spade, which was the progenitor of the 30-ton-bite steam scoop-shovel, he dug a trench from the river to the stables, dumping the dirt in the river to create a head of water that would take the River Alpheus on a one-day tour through the Augean stables. By sundown, the clean-up job was done. Hercules scooped the dirt back out of the bed of the River Alpheus, re-established its banks, tamped the soil back into the trench, replaced the divots, and called the king to inspect the job.

King Augeas, he of the beam of streaming light, cast his radiations on what had appeared to be a matched herd of three thousand jet-black cattle and found instead the same number of lily-white bossies, every one outshining Borden's Elmer or Elsie. The king refused to pay Hercules. Excuse: He touched the sacred river.

Several morals seem to be buried in this story of Hercules' engineering techniques. More important, however, is the fact that the early Greeks were wise enough to consider engineering an activity worthy of an Olympian god.

The stories of Hercules' exploits as ordinarily told do not appear to be narratives of engineering accomplishments and cultural developments, but they are, nevertheless, when their symbology is properly understood.

It should be pointed out that at the peak of his career Hercules directed his powers toward destructive purposes, went insane and from this condition was saved by being required to work under

direction on constructive projects. This situation may have its modern counterpart in recent events.

The Phoenicians had a Hercules before the Greeks, but this entity was entirely a god although participating in the affairs of men. In him was included much of the Greek Hephaestus (Vulcan) and he, too, was a patron or founder of industrial arts. The still earlier Sumerians had a combination man-fish god who taught the human race language, the arts, and the sciences.

As myths have later origins, more subtle ideas are incorporated in them. The walls of the first city of Thebes, in Greece, were built by Cadmus whose fame as an engineer was exceeded by that which he gained from his experiment in trying to produce a new race by planting the dragon's teeth which, however, yielded a crop of giants so unsatisfactory that Cadmus found it necessary to exterminate all but a few of them.

When the enlarged city of Thebes required, much later, a new wall, the job was done by the brothers Amphion and Zethus, of diametrically opposed personality types. Zethus was a tough guy, much like Hercules who, when an effort was made to teach him music, hit his instructor over the head with a lyre. Amphion loved music and he had good reason for doing so.

Zethus used his brawn to enable him to drag heavy stones for building the wall but Amphion, following his trail, had only to strum his lyre to make still bigger stones follow him wherever he led the way. Here was the old story of brains versus brawn, and another version of the story of Epi- and Pro- metheus whose descendants are still with us.

There is nothing mythical about using music to move stones. At an Engineering and Power Show in New York (pre-war) there was exhibited a clever device in which an upward inclined tube was set vibrating to a musical note, and sand and other small particles placed at the lower end moved energetically up the incline and spouted from the top like a stream of water. Music in this case had very specific power to move stones. Nikola Tesla moved machines and nearly shook a building down by using a

musical vibration.* It also moved Mark Twain's bowels—much to his surprise.

The great majority of mines throughout the country use a device for ore-treatment which consists of a tray set vibrating to a combination of low frequency musical tones which caused ground ore fed to one end to be moved along it and separated into richer and poorer grades of ore.

Hercules has been described as the first great engineer. He flourished about 1250 B. C. It is obvious that he could not have been the first. Copper was mined and worked in Cyprus in 3000 B. C., there is evidence of a bronze age in Crete about 3500 B. C., and extensive use of this and other metals in Sumeria in the Tigris and Euphrates valleys at as early an age. Such use of metals entailed engineering practices. Unfortunately we do not have sufficiently extensive records of these civilizations in the form of preserved literature to provide us with stories of their engineers.

All the early cultures had their own Hercules, many of them using the same name. Evidence of the worship of Hercules is found from Spain to India. Some scholars have assigned to Hercules the role of Messiah, pointing out that he fits into the generalized concept, being divinely conceived and having led a life of struggle for the benefit of humanity.

* *Prodigal Genius—The Life of Nikola Tesla,* by John J. O'Neill. Ives Washburn, Inc., New York.

5. RULING THE RIVERS

STAYING alive, as a member of a congenial group, and being happy about the whole situation, is the simplest statement of the universal problem that has not changed since history's unending succession of centuries started their parade through time. The details may change with place and circumstances but the basic situation remains the same and will continue without alteration in the torrent of tomorrows that will carry us into a future that fascinates us with its unfathomed possibilities.

In the past, however, man has, at times, looked to the future with forebodings of dire consequences that might ensue from his muscle-powered battle to extract a living from his surroundings. The primary problem he has ever been forced to solve is that of obtaining a supply of food and drink. Where nature provided year round supplies on trees, shrubs and root-plants, the problem of nutrition was not too difficult for early man. In places where plant food sources were not available the year round, he could trap animals and catch fish to round out his seasonal supplies. In some areas there were animals that also had food problems to solve and, only too frequently, it was a question as to which would solve the food problem most effectively.

This limited man's residential areas to some extent. The deserts were inhospitable; they grew little food and the water supply problem was a severe handicap. The river valleys afforded lush vegetable growth and a maximum supply of fresh water which would also supply fish for the menu. The larger and more dangerous animals preferred upland areas. The river was a convenient highway.

No matter where he went, man found problems. The river

valleys provided the greatest number of ready made solutions to his food and drink problems, but it did not solve all of them. Rivers were not constant. In one season they would flood the entire valley and in other seasons they would run practically dry. The season when he would want the land reasonably dry for planting was the time when the river would be in flood, and the season when he wanted water to nourish his growing crops would be the time when the river would diminish to a trickle.

Observation of springs undoubtedly gave man the clue to underground supplies of water but, at any rate, he was early in the possession of knowledge that he could obtain water by digging at times when surface sources were completely dry. Hauling a bucket of water to the surface was not too high a price to pay for the water needed for drinking but this method was entirely inadequate for the task of providing a drink for thirsty acres.

A series of buckets on endless ropes moving over cylindrical blocks which could be turned first by hand and later by a treadmill made the task somewhat easier but the method was still inadequate for watering land.

Saving the flood waters for use in the dry season, just as the grain was saved from one harvest to the next, was an obvious solution of the problem but that was a task beyond the power of single families or small groups of families. As river valleys became more densely populated, common needs became the catalyst for common efforts to meet them and large scale projects became possible. The organized community sense developed.

Man undoubtedly arrived at the plan of building storage dams through his own initiative but such projects were not entirely original with him. Beavers had been building dams for similar purposes for a mighty long time before man tackled the job on a community scale. It is probable that man, too, had built them on a small scale but the records of these activities are not available.

The beaver was a very capable engineer. The entire animal world exhibits a high order of engineering skill. The spider's

web is a structure well worthy of admiration. The Engineering Institute of Canada has recognized the beaver's abilities by giving it a place on the badge and official seal of the society. Our bridge builders could justly accord credit to the spider as a pioneer in their art. He was a designer, maker of his own "steel" and a construction engineer. He even invented the first telegraph line by stringing a line from the center of his web to his distant den where he received vibratory signals when a customer entered his structure. Many such originals of modern inventions can be found among the works of the animals.

The beaver was a good civil, structural, hydraulic, and mechanical engineer, and a capable geologist, up to the limit of his needs. He was supplied with built-in tools, his wood-chisels in his mouth and a trowel in his tail.

With two teeth highly developed for a specialized job he was able to perform extensive tasks in wood cutting, felling even large trees. The trees felled, he cut into lengths required for his building operations.

Using these sticks and stones, clay, and other materials readily available in the river bed and on nearby banks, the beavers erected structures which were not only retaining dams but also their homes. The lakes impounded behind their dams were the breeding grounds for the fish that supplied the principal item of their food. They built well-ordered and economically sound communities.

Beaver dams demonstrate a keen understanding of hydraulic principles. When the head of water was too great to be handled by a single dam, the beavers constructed multiple dams to reduce the strain on each structure. They weighted their dams with stones and plastered them with impervious clay worked into position with their broad tails.

As long as he was satisfied with his built-in tools the beaver was limited in his operations. Man, using external tools, has been able to extend his operations, to build bigger and higher dams

with a wider choice of materials, but his techniques are fundamentally those of the beaver.

In the earliest days, every man was his own engineer. The extent of his projects was limited by the strength of his arms and the carrying power of his back as well as by the ingenuity of his brain and his appreciation of comfort beyond his immediate necessities of food and of shelter. As a matter of economy he probably chose a cave in riverside rocks for a habitation, enlarging and shaping it to his needs as requirements arose and time and effort permitted. The woman of early days was undoubtedly just as good an engineer as the man.

Before dense populations developed in the river valleys, community projects of more than moderate size were not practicable. The individual family had to shape the ground and their whole environment to their needs as best they could. A typical situation would be a family living in a cave in the limestone cliffs, a little back from the river bank. The opening of the cave is partly walled by pieces of flat limestone piled on each other from bottom to top, leaving space for a low, narrow door.

Inside the cave is a woman and two small children. The woman is engaged in making a large bowl by hollowing a block of limestone by pounding the larger block with a hand-size rock —the home factory.

When this man laid stone on stone loosely to wall up as much as he desired of the front of his cave, he was engaged in a building operation. It was a crude process but the materials used and the technique of utilizing them provided the desired results. The wall was not air-tight, but the moderate weather made it unnecessary to have it so and the chinks permitted the admission of desired light and air. It was very primitive air conditioning, but it met all the requirements. The whole set-up provided shelter, protection, comfort, and storage space with a minimum expenditure of material and effort. That meets engineering standard requirements at that cultural level.

The pile of stones which he laid in the ditch to provide a level walk from the river and the garden to the cave was indulgence in what may appear to be a luxury and actually was a luxury in an earlier state of development of this homestead. In the beginning, the routine activities of gathering food and putting the cave in shape to provide shelter took all of his time. He could better afford the annoyance of wading through the ditch or walking the longer way around on the dryer ground at the far end of the ditch than he could afford the longer time and greater effort required to split the limestone slabs to carrying size and to lay them in the ditch. Once the cave was in comfortable shape the time formerly spent on that could be spent on building his little causeway. When the time became available for building it, the causeway was no longer a luxury but a necessity. It saved him the time that would be spent traveling around the water, or the time required to clean the mire off his legs if he waded through the ditch. This time could now be spent in further constructive work.

Every man had the responsibility for being his own engineer. Under primitive conditions he must perform all engineering operations required; as cultures develop and division of labor with its concomitant division of production becomes desirable, engineering operations can be shifted to those most competent to perform them.

Simplest engineering operations confined to small areas are adequate to meet the need of this individual and his small family, and to maintain them on a low cultural level. This individual, under improved circumstances, would be capable of utilizing the benefits of higher cultural levels for greater satisfaction in life.

If there were no death to halt activities, no diminution of maximum physical power to reduce productive effort and if he had an infinite span of life in full activity, this man would, in time, be capable of producing, through accumulation of steps

of advancement, the artifacts and conditions of any cultural level no matter how high its plane. The individual represents the expression of the miracle of life. The life span in an individual is limited in time. The individual, however, through a co-operative biological engineering undertaking can bring about the reproduction of himself. The miracle of life is expressed simultaneously in many individuals, all of whom have much in common.

Just as two individuals can co-operate biologically to produce a multiplicity of expressions of the life phenomena in other and new individuals, so can many individuals co-operate in engineering projects to bring about a great enjoyment of the benefits to all the participating individuals.

Can the individuals along this line of cliffs afford the effort required to produce the engineering works that would enable them to make easy contact with each other and thus organize a social unit?

This reduces to a simple problem of energy utilization. Nature provides adequate sources of energy in the form of food. When these sources are adequate in an environment, a given amount of work expended in controlling growth and collecting food will return in energy gained from the food many times the energy expended in obtaining it. If the return is tenfold greater than expenditure and there are four members in the family, then there is an excess of energy available for activities other than food production.

At first this excess must be expended in construction of the home and improvements of immediate surroundings which remain reasonably permanent so that the work need not be repeated. Later this excess can be expended on building up a social structure. After the caves have been improved, gardens established, and fish weirs constructed, work can be done to expand the community to care for population increase.

Life on this level is lived under conditions in which the re-

sources of nature are used in the form in which they are found, with minimum effort to shape or change them in any way. Choice is severely limited.

The next great step in engineering progress came when raw materials were altered to provide more useful substances; such a process was the making of bricks from clay, moistened and sun-dried. The immediate reward for this accomplishment was the greater freedom of choice in location of the home, and complete elasticity in planning the size and shape of the family habitation.

Utilization of this new, versatile article, the brick, imposed on the user the necessity for developing the techniques of building walls and designing structures the like of which did not exist in nature. Invention of bricks and the building of walls was looked upon as such an important development by the Phoenicians that they conferred deification on the reputed inventor and, after his death, worshiped him as a god under the name Diamichius.*

Without the invention of the brick the city could not have developed. The invention was not exclusive with the Phoenicians; it appeared independently among all peoples. As important as this invention was as the precursor of the city, even more fundamental was that biological prerequisite, the ability of the family unit to produce or gather more energy in the form of food than was expended in this process. The ratio of a city area's population to the population of a food-producing area will always depend upon the ratio of the excess food energy produced by the country population to the food energy required to maintain the country population. The excess supports the city.

Rural communities in which the population is widely dispersed but in which all the family units are dependent upon a single factor—for example, a river for supplying soil nutrition and moisture, may be as tightly organized in a social unit as a city and undertake co-operative ventures in which a high order of engineering skills is required.

* According to Eusebius Pamphilus, a third century Palestine historian.

Rivers only too frequently vary over a wide range in the amount of water flowing in them. In dry periods they reduce to a trickle and in wet seasons become roaring, destructive torrents. In flood, the moisture for irrigating farms, and the silt for rejuvenating soils, would be lost unless measures were taken to conserve the water.

One of the earliest large-scale applications of river control for irrigation was in Sumeria and may date back to 4000 B. C. Here embankments were built around farms to shut out the high waters of the Euphrates and Tigris Rivers at flood. Farther back from the river, systems of ditches were built into which river water was permitted to flow at controlled rates. Low areas were banked as reservoirs to extend the flow into the ditches. Two millenniums later an immense reservoir was built by Nebuchadnezzar. It had an area of about 1,250 square miles and was supplemented by an extensive system of canals, an engineering achievement of first magnitude.

For more than 4,000 years the engineer-priests of the Egyptian dynasties maintained an unending vigil over the Nile because the prosperity of that country was entirely dependent upon annual soil rejuvenation from silt carried by the river and upon adequate supplies of water at proper levels for irrigation.

Development of geometry and its intensive application to surveying is credited to the Egyptians because of the necessity for re-establishing the boundaries of farms after each flood. This was a minor problem, if any problem at all. The real difficulty was establishing the actual levels of the bench marks throughout the river valley, for priests early discovered that the Nile valley was seismically active. It was continually undulating with a slow motion and probably on some occasions not so slowly, and this affected the flow of the river. A rise of the bed at one point and an equivalent sinking farther up the river would be the equivalent of a dam's shutting off, at least temporarily, the flow of water to the delta region and flooding upstream areas.

Herodotus reports the tradition that a great lake was formed

in the Nile valley beyond the delta and later disappeared. Manetho records in his, the most ancient listing of the Egyptian dynasties, that, during the reign of a number of specified kings, cataclysms visited Egypt, but the nature of them is not recorded. The Fayum is today below sea level and archaeologists have recovered remains of the early civilization fifteen feet below the present level of the silt.

A new explanation of the enormous statues of Egyptian kings, their peculiar locations and dimensions is supplied by Hekekyan Bey, a civil engineer at one time in the Egyptian Nile Service. These statues are, he records in a book, *Egyptian Chronology,* printed for private circulation, the equivalent of bench marks which record, in a way that was understood only by the priests, the facts relative to elevations of the Nile valley with respect to the level of the Mediterranean and Red Seas. The data are hidden in the dimensions of the sub-bases, bases and other dimensions of the statues to record the instability of the river bed, its rising and its falling, mostly subsidence not uniformly compensated by silting.

Man here had progressed to long-range engineering, and this offers a suggestion that engineers might, with profit, become interested in ancient history. There is much in classical literature that they will find of interest to them.

Large-scale engineering enterprises started early in Egypt. Herodotus records the statements of the priests that Meme, the first king of Egypt (perhaps about 3500 B. C.), diverted the Nile to a new bed by digging a new channel and building an embankment across the old channel at Memphis. That dam, or levee, is still in place today performing the same service for which it was built.

About 2000 B. C., Rameses II, whom the Greeks call Sesostris, a world conqueror out of Egypt, brought back enough slave manpower to tackle the enormous job of making the entire delta region a network of canals creating a series of new outlets for the Nile east of the Damietta River mouth, supplying fresh water

to this large region. The real estate boom greatly increased the royal revenues and permitted a most bounteous patronage of the arts. An early successor, Senusret III, reclaimed the swamp known as the Fayum Oasis, up the river valley, by building a retaining wall twenty-seven miles long, which created the artificial Lake Moeris and made available for agriculture 25,000 acres. The region became one of the richest in Egypt.

Another 1,500 years elapsed before the next big water engineering job was tackled, building a canal from the Red Sea (or Arabian Gulf, as it was then called) to the Nile. According to some records it was started under the reign of the Pharaoh Necho (or Niku) about 600 B. C., and, according to others, it was begun as part of the ambitious irrigation project of Sesostris very much earlier. Its date of completion is almost as uncertain. Darius, King of Persia, a conqueror of Egypt, is credited with finishing the task about 500 B. C., as are also the Egyptian Ptolemys about 250 B. C. The canal extended a distance of ninety-two miles, from Suez to Bubastis in the neighborhood of what is now Cairo. Depressions saved digging over thirty-two miles of the route. Its depth was fifteen feet (Pliny makes it thirty) and its width from 108 to 165. In less than fifty years, drifting sand overcame maintenance efforts. It was redug with the same result. About 750 years later, the conquering Arabs reopened it, but by 767 A. D., the drifting sands were again victorious.

The modern Suez Canal has about the same length, a depth of thirty-one feet and a surface width of 420 feet. It passes through a series of lakes but thirty-five miles were cut through upland, an elevation of eighty feet being encountered near the southern end.

The greatest engineering feat of all time, in the matter of magnitude, is that recorded in the Chinese annals of the Emperor Yu (or Yau), probably a little earlier than 2000 B. C. The records are in poetical form which was the common practice in those days in China as well as elsewhere, as witness the recording of the early history of Greece in the Homeric poems. As the event is

recorded, "The ocean descended and was trapped in the mountains and the coastal plain was rendered uninhabitable by water." The event that may have happened could have been a seismic disturbance in which there was an uplift of a mountain range in east central China, which blocked the course of the east flowing rivers, possibly by elevation of their beds, causing the waters to gather in a great central lake that flooded a large area, creating the "ocean." The seismic disturbance may have been accompanied by long continued torrential rains such as fell during Noah's flood. It is probable that the mountain-raising disturbance would have been accompanied by a crumpling of the coastal plain to the east changing normal drainage channels.

Emperor Yu sought engineers "to get the ocean out of the mountains." One failed and lost his head. Another succeeded but he remains unnamed and Emperor Yu gets credit for the achievement. The successful solution appears to have involved the cutting of a channel through the elevated land to let the waters trapped in the valleys between the mountains flow into the old bed of the Hoang-Ho River. This did not improve the situation in the coastal plains so the channel was blocked at the point where it was recently cut. A new point was selected further north. Here a new cut was made. There was no existing river through which the waters could escape but they made their own channel, and apparently cut it quickly and deeply, so that a new river was formed that emptied into the Gulf of Pechili. This is the present Hoang-Ho River. Its mouth is 350 miles, air line distance, from the mouth of the old river which emptied into the Yellow Sea. The mountainous Shantung Peninsula lies between the two river courses. Yu shifted the river from the south to the north side of this ridge. On a number of occasions since then, the Hoang-Ho has returned to its original bed.

The world's longest canal was built in the coastal region of China. Its construction required 200 years. It was begun in the seventh and finished in the ninth century A. D. It extends in a north-south direction from near the mouth of the Hangchau

River to Peiping, a distance of 825 miles. One of the principal reasons for building this, the Imperial Canal, was to permit merchants to escape the depredating pirates who infested the coast of the Yellow Sea. The Imperial Canal is more than twice as long as the next longest, the Erie Canal, which extends 387 miles and connects Lake Erie with the Hudson River.

The ancients achieved a pre-eminence as canal builders which has not been equaled in modern times. They responded, however, to necessities which no longer exist. Then canals made large areas habitable and suitable for food raising, and the transportation facilities were largely a fortunate dividend. As other types of land came under cultivation and better means of transportation overland became available, canals lost much of their early significance. Today military aspects are much more important than commercial transportation factors.

Each group developed independently its techniques of controlling land and water relationships. Northwestern Europe had developed its canals and its dikes to shut out the sea from fertile lowlands before the coming of the Romans to that region. The Romans, in their homeland, never faced the necessity for draining and reclaiming the Pontine Marshes. Although many efforts, some very recent, were made to improve conditions there, they remain today a none too pleasant region.

Suitable credit may be accorded for the building of the Panama Canal, but as a civil engineering feat it was not notable either for the magnitude of the operations involved or the spectacular nature of the difficulties overcome. The aspect in which the Panama Canal achieved its great glory was as a magnificent feat of sanitary engineering. The French builders who first tackled the job failed because a scandal developed in which charges of simple dishonesty in handling the public funds were made and caused the French people to lose confidence in the operators to such an extent that they refused to appropriate funds for the project. Other considerations of an international and political nature may have been involved. From an engineer-

ing viewpoint the French contractors could have carried the canal to completion, but they would have attained their goal at a frightful cost in human life which would have given them, as engineers, no higher ethical status than that of the engineer-priests of Egypt in their wastage of slave labor. This situation should indicate that the purely civil engineering activities do not comprise the totality of an enterprise, that the integrity of the engineers is as important as adherence to conservative hydrodynamics, and that events which may be legally charged to "acts of God" may be morally chargeable to inadequate ethical engineering canons and insufficiently evolved concepts of social responsibility.

An engineering job is not limited by the area of the plot in which a structure is erected; it is as large as the most far-reaching, beneficial, or ill effect it produces in the present or future. Any project which does not make proper provision for handling these effects is not properly engineered. The river control projects undertaken in the United States in recent decades are marvels of magnificent achievement. Among these we have the Mississippi, Tennessee, Colorado, Columbia, and, recently, the Missouri Valley projects. Of these the first, carried out under the Tennessee Valley Authority, has come closer to meeting the foregoing standard than any modern or ancient achievement.

There is an ancient precedent for these projects. Nebuchadnezzar, about 600 B. C., set up and carried to completion what we would today call the Euphrates River Authority project. It was set in the background of what may seem to us a relatively simple culture, but this simplicity may have created as many problems as the more complex civilization in which the modern river valley authorities operate.

Boulder Dam, a structure 727 feet high in the Columbia River, contains the same volume of material as the great pyramids in Egypt, and the Grand Coulee Dam in the Columbia River with its earthwork structure 525 feet high contains much larger volumes of material.

The Tennessee Valley Authority has twenty-one major dams, five of which were taken over from private owners. They make the river navigable for 650 miles and otherwise profitably control the flow from a watershed of 41,000 square miles. The waters, formerly producers of destructive floods, have been harnessed to yield their energy usefully through a hydro-electric installation with a capacity of 2,500,000 kilowatts.

More important than the commercial experiments and political advantages accruing from this development is the recognition which the creation of the Tennessee Valley Authority project gives to the concept that the dimensions of an engineering project are co-extensive with all its effects and that engineering entities can be organized into the counterpart of social units among human beings.

6. THE ENIGMA OF THE CITY

MAN, we are told, was made from a lump of clay into which the breath of life had been blown. Another very useful object was made from a lump of clay on which the heated breath of a furnace had been blown. This was the common brick. The brick bears the same relation to engineering that the first man bears to civilization. We look upon the brick as a lowly object of humble birth but, as stated earlier, the ancients were so appreciative of the gift of the brick that they made a god of the man whom they credited with having invented it.

The brick is the module of the city and the city is the symbol of civilization. Born into it were infinite possibilities of variability and adaptability. It may be contended that the brick has descended from the position of prime importance as a building material which it formerly held and is now used in structures not of primary significance in the builder's and the engineer's art, but the claim can be disallowed without distorting the facts.

The brick has not developed into just two families—face and common. The ancestral spirit of the brick is in many things not ordinarily associated with it. If there were such an individual as a culture genealogist, he would be able to demonstrate that many of our snooty modern technological developments are direct descendants of objects that originally came into the engineering world on a figurative Mayflower brickbarge.

A four-story poured concrete monolith factory may look down upon the common brick and disclaim any family relationship but this concrete complexity is nothing more than a brick of special composition and titanic dimensions shaped to a unique contour.

The haughty granite blocks of the monumental municipal

building, it may be claimed, never went through a brick yard. The granite block is, nevertheless, a brick. The brick yard from which it came was established a long, long time ago and was supplied with a very large furnace. The heat that baked the granite brick was volcanic heat generated within the crust of the earth. The heat was so cheap and present in such great plenty that it was possible to carry the baking process to the point at which the component clays and sands and gravels were melted and fused. It was not a rush order, so plenty of time was taken to let the material cool slowly and crystallize. And there is really no fundamental difference between the clay shaped to the module dimension before it is baked, or cut out of a large mass production block after it is baked.

The steel skeleton of a skyscraper stays within the brick category. Disarticulate such a structure, dismember its beams, columns, and girders and what remains? Extended, elongated rectangles composed of metals; a metal brick of unusual dimensions.

Truly the brick is the module of the structural art. It is the ubiquitous unit with which the engineer has constructed many things; it is the architect's atom. It was in the first cities that the miracle of the brick expressed its earliest and most fruitful manifestations. Here the miracle of the brick was also a manifestation of man in his best expression as well as in aspects which, fortunately, are irretrievably buried in the past.

Babylon was the most magnificent city of ancient civilizations at the peak of its power and glory. It had not always been thus nor did it always remain so. If we cared to watch the panorama of history unfold we would see it arise out of the sands and go back under the sands and might wonder to what purpose its coming was dedicated and for what reason it disappeared.

That strange engineering synthesis which we call Babylon was born, lived, grew, died, and was buried, but the module, the bricks out of which it was constructed, experienced rebirth in other cities built out of the debris of their predecessor.

Whence came the engineering talent which made possible the building of so magnificent a city? Its construction is ascribed to a king. This has a familiar sound to engineers of today.

We see a magnificent bridge built across a mighty river and become an essential artery in the life traffic of a nation. On the bridge we find a bronze tablet announcing that the bridge was built by Mayor Demos O'Populi and dedicated in the year Steenteen Hundred and Octeen. He shares the lower quarter of the tablet to give credit to aid received from his commissioners of Streets, Highways, Bridges, and City Planning. Not a word, however, may appear to indicate that the bridge was planned and built by the engineering firm of Pier, Spanner & Truss.

It may have been so in the early days, but there is also the possibility that in those days a man with a flair for engineering and a powerful personality might well have gained access to the throne. The great Sargon I, presenting a biography containing many elements closely paralleling the story of Moses, made no claim of royal birth but bragged of his humble origin. He is credited with having founded the great Semitic empire of Babylonia. This founding, however, was done not by building but by military conquest, from Nineveh and Ur, of the non-Semitic Sumeria which had flourished for two thousand years or more before Sargon was born (about 3000 B. C.) and in which the original city of Babylon was built.

The Assyrians who conquered Sumeria, a country which was as antecedent to them as ancient Egypt is to us today, created myths out of fragments of tradition which they dramatized for their own glorification and proceeded to incorporate in their history the story of an Assyrian queen Sammuramat who is credited with having built the city of Babylon in three years. There actually was a queen by that name but, according to records now available, all she did was to reign for three vacant, uneventful years.

The myth passing into Greek hands resulted in the name being translated to Semiramis and the myth becoming further

idealized. By the time the story got into the hands of Diodorus Siculus, of Sicily, the Roman historian, Semiramis became elevated to the status of the female master mind of the ages, statesman, world conquerer, and master engineer of all times.

It is the engineering feats credited to Semiramis which will interest us. It will be desirable to mix a reasonable degree of skepticism with acceptance of these traditional records. Nevertheless, in spite of the idealizations, there is the hazy record of solid accomplishment by someone behind them.

Semiramis is credited with having dug a vast number of lakes and mounds, to no purpose, apparently. Neither the Assyrians, Greeks, nor Romans, however, ever handled as a national problem the control of a river for irrigation with the incidental need for embankments and reservoirs, so had little knowledge of the significance of such structures. The Assyrians found these in Sumeria and, not understanding them, idealized them, and they became the handwork of Semiramis.

In Sumeria was developed the ziggurat, the temple with the square base and pyramid tower with each story of it stepped back. These towers, sometimes seven stories high, with a base fifty feet high, were the prototype of the stepped-back type of architecture now required in tall buildings in large cities. We find Semiramis credited with having built mounds a mile high and proportionately wide at the base which, undoubtedly, is an understandable exaggeration of the ziggurat.

In the story of Semiramis, nearly three thousand years old, we find recorded a technique which was reported, during the recent war years, as a great original idea in engineering achievement in our shipbuilding effort—the building of ships in sections which were assembled into a finished vessel. Semiramis in preparing for her conquest of India built her fleet at home in sections easily transported and carried them to the point where they were required and could be quickly assembled for a flash attack. In spite of her clever preparations she was driven home in defeat. It may be of interest to note that the ancients did not

hesitate to ascribe these engineering achievements to a woman.

A later queen of Babylon, Nitocris, is credited by Herodotus with engineering exploits hardly less spectacular. While earlier kings in Sumeria, the more ancient kingdom, are credited with having created something akin to a Euphrates River Authority to make the river navigable from the Red Sea (then so described, now the Persian Gulf) to the northernmost bounds of the kingdom, Nitocris operated on the river near the northern boundary, above Babylon, for the opposite reason, to make it more difficult for the Medes to reach Babylon. It was an easy, fast, and direct trip down stream from the main roads and she did not want these particular foreigners coming to the city and spreading their subversive, un-Babylonian, political doctrines to the youth of her city.

To make the travel more difficult she changed the course of the Euphrates from a straight line and caused the river to swing through three gigantic loops so that its banks made three contacts with one relatively small city. Rivers, however, do this of their own accord and without the aid of queens.

As a part of this project she dug a great excavation down to the water table which became a lake and reservoir and in which the deep channel skirted the banks of the lake, making the entire circuit of the lake necessary for boat travelers. The banks of the lake were covered with a stone plating.

Advantage was taken of this development to carry on another project within the city. She diverted the entire flow of the river into the lake, leaving the stream bed dry where it passed through the center of the city of Babylon. While the riverbed was dry, she laid the bed and banks with stone (probably brick and tile) for the whole fifteen miles of its course through the city and, at the center point, she built a bridge.

The bridge was built of blocks of stone bound together with iron and lead. In the daytime, square wooden platforms were laid along from pier to pier so that the inhabitants could cross the stream. At night these platforms were withdrawn to

prevent people from crossing in the dark to commit robberies.

For a description of the city of Babylon we have the words of Herodotus (484–415 B. C.) who visited the place during the reign of Cyrus the Great after it had come under Persian domination. Babylon was not then in its earlier state of greatest magnificence. It had been almost destroyed in 683 B. C. and rebuilt to its highest state of development by Nebuchadnezzar about a century later (580 B. C.). Persian conquerors claimed its destruction in 514 B. C. but Herodotus, on visiting the place more than half a century later, found the city quite impressive (*Herodotus,* Loeb Classical Library, Harvard University Press, Cambridge, Mass.). He says:

> The city stands on a broad plain and is an exact square fifteen miles in length each way so that the entire circuit is sixty miles. While such is its size, in magnificence there is no other city that approaches to it. It is surrounded, in the first place, by a broad and steep moat full of water, behind which rises a wall eighty-four feet in width and 336 in height.
>
> And here I may not omit to tell the use to which the mould turned out of the great moat was turned nor the manner in which the wall was brought. As fast as they dug the moat, the soil which they got from the cuttings was made into bricks and when a sufficient number were completed they baked the bricks in kilns. Then they set to building and began with bricking the borders of the moat, after which they proceeded to construct the wall itself, using throughout for their cement hot bitumen and interposing a layer of wattled reeds at every thirtieth course of bricks.
>
> On top, along the edges of the wall, they constructed buildings of a single chamber facing one another, leaving between them room for a four-horse chariot to turn. In the circuit of the wall are a hundred gates, all of brass, with brazen lintels and sideposts.
>
> The bitumen used in the work was brought to Babylon from the Is, a small stream which flows into the Euphrates at the point where the city of the same name stands, about eight days' journey from Babylon. Lumps of bitumen are found in great abundance in this river.
>
> The city is divided into two portions by the river which runs through the midst of it. This river is the Euphrates, a broad, deep, swift stream, which rises in Armenia and empties itself into the Persian Gulf. The city wall is brought down on both sides to the edge of the stream; thence from the corners of the wall there is carried along each bank of the river a fence of burnt bricks.

The houses are mostly three or four stories high; the streets all run in straight lines, not only those parallel to the river but the cross streets which lead down to the waterside. At the river end of the cross streets are low gates in the fence that skirts the stream, which are, like the great gates in the outer wall, of brass and open on to the water.

The outer wall is the main defense of the city. There is, however, a second inner wall of less thickness than the first but very little inferior to it in strength. The center of each division of the town was occupied by a fortress. In the one stood the palace of the kings, surrounded by a wall of great strength and size; in the other was the sacred precinct of Jupiter Belus, a square enclosure of twenty-four hundred feet each way, with gates of solid brass, which was also remaining in my time. In the middle of the precinct was a tower of solid masonry six hundred sixty feet in length and breadth, upon which was raised a second tower, and on that a third, and so on up to eight. The ascent to the top is on the outside by a path which winds around all the towers.

When one is about half way up, one finds a resting place and seats, where persons are wont to sit some time on their way to the summit. On the topmost tower there is a spacious temple, and inside the temple stands a couch of unusual size, richly adorned, with a golden table by its side. There is no statue of any kind set up in the place, nor is the chamber occupied by nights by anyone but a single native woman, who, as the Chaldeans, the priests of this god, affirm, is chosen for himself by the deity out of all the women of the land. They also declare—but I, for my part, do not credit it—that the god comes down in person into this chamber and sleeps upon the couch.

Excavations made in recent decades have uncovered parts of the walls of Babylon and reveal that the walls were of much greater thickness than that given by Herodotus. The outer retaining wall was 23.5 feet thick and the inner retaining wall 44, while between them was a sand fill to a thickness of 69 feet, giving a total thickness of 136.5. Herodotus gave the thickness as 50 royal ells (or cubits) which is equivalent to 84 feet. A single setting of a slide rule will indicate the probable reason for this error as it indicates the measured thickness of 136.5 feet is equal very closely to 80 royal ells. The "50" royal ells of Herodotus were probably a typographical error.

The building of the walls of Babylon may be the biggest material handling task ever tackled by the human race. The uncertainty is due to lack of accurate data about the dimensions

of the Great Wall in China. The volume of the walls of Babylon is fourteen and a half billion cubic feet. The length of the Great Wall is 1,250 miles. It is not uniform in design throughout its length. If the average cross section were one thousand square feet which would give a thickness of twenty feet and a height of fifty feet, the volume of the whole wall would be approximately six and a half billion cubic feet which is less than half of the volume of the Walls of Babylon.

If a man would lay thirty cubic feet of brickwork in a day, the building of Babylon's walls would require 250 million man days. If one hundred thousand bricklayers were employed, working without holidays, seven years would be required for laying the bricks. It is probable that ten or more men were engaged in auxiliary activities required to service the one bricklayer so that the task represents a probable three and a half billion man days, or ten million man years.

Were the walls effective in making the city impregnable to attack? No. At least three times the city was successfully attacked and extensively destroyed. On one occasion the river was the vulnerable spot. The attackers, working far upstream, diverted the river to a new channel, and rushed inside the walls through the vacated, dry, river bed extending through the center of the city.

Using the wisdom that comes with hindsight, it may seem that the effort spent in building the walls of Babylon was ineffective and that the rulers who so wasted the time, effort, and resources of their people, committed an error of tremendous magnitude. This is undoubtedly true. Would modern man be likely to commit an error of such magnitude? The question might be answered by looking at the record. In carrying on World War II the United States expended approximately sixty billion man days, or two hundred million man years. This is twenty times the effort expended in building the walls of Babylon. Man hours today are expended in controlling power machinery, and the individual has an output of at least one hundred times that of

an individual in the days of Babylon so the productive effort spent by the United States in this war was two thousand times that expended in building the walls of Babylon.

The effort spent on the Walls of Babylon was invested in a defensive device—that didn't defend. The effort spent on World War II was invested in an offensive activity, directed entirely at destruction. The amount of destruction is at least equal to the effort expended to this end and probably many times greater. What man could have achieved if only he had expended all that energy toward constructive ends!

After the war had started it was magnificently engineered. It was a superb example of scientifically directed technological skill. The world's finest brains were directed to the complete destruction of a central, eastern, and southern area of European civilization and an Asiatic civilization. The most magnificent display of scientific thinking and engineering effort was expended on the war; but not one iota of scientific thinking was employed in trying to solve the problem which led to the war, or applied in a serious effort to prevent it.

7. CIVILIZATION'S BLIND DATE

MYSTERY still enshrouds one of man's most interesting and most ambitious engineering efforts. Considering the facilities available at the time, it still holds the record after a lapse of some thousands of years. This feat was the building of the Great Pyramids in Egypt. The largest of these structures covers more than thirteen acres and is almost as high as the Washington monument. This is the pyramid known by the names Cheops, Gizeh, and Khufu. It has a square base 746 feet on a side and a height of 480 feet. Its volume is 93,724,693 feet, or 3,471,259 cubic yards. It is a solid stone structure. Its axes are oriented with extreme precision in a north-south and east-west direction. It was long believed that the pyramids were sepulchers of the Egyptian kings who caused them to be erected but this is very definitely not the case. The reason for building them is not known, but may be associated in some way with a tremendous cataclysm of an unknown nature that visited Egypt. When we learn the nature of that cataclysm, we will know more about why this gigantic monument was built, and the smaller ones that followed it.

The engineer-priests of four thousand years ago were making, in their pyramid-building feat, an effort to pass on to posterity, to the engineers of today, the story of an event that was worth while recording at tremendous cost. No other way was known to them of making a record that would survive a repetition of the conditions that caused them to undertake the preservation of the story in stone. The names associated with it are, probably, not even the names of kings, but clues to the reasons for the projects.

Deriving the meaning from the roots of the words we have in

the names of the pyramid, Cheops—Great Fire Eye; Khufu—Fire Ever Existent; and Gizeh—Man of God in Us!; and the word pyramid—Far Resplendent Fire. For these and other reasons it is probable that the building of the pyramids had something to do with a cataclysm in which fire was the dominant factor, probably fire from the sky. Just what this phenomenon was is anybody's guess.

There is a gallery pointing skyward that starts deep down in the pyramid and has its opening far up on the north face. It was originally covered by a swinging stone door. This long, tubular gallery points to a spot in the sky which was the north pole of the heavens about the year 3000 B. C. This point is now in the constellation Draco and is, incidentally, the direction in the sky toward which the entire solar system is moving according to the measurements of our modern astronomers.

There are some slight deviations in the orientation of subsequent pyramids in the group—those built at later dates. The builders demonstrated that they were entirely competent to achieve a high degree of accuracy so the slight deviations may be meaningful. The earth's axis is always wobbling. Did the pyramid builders seek to give us a permanent record of perhaps some greater than usual motions? Or, knowing their successors would be able to derive knowledge of these motions, did they just use the north pole pointings to indicate the time of some tremendous event which the pyramids were symbolizing?

In the Book of Job, in the Bible, is the story of fire descending from Heaven and devastating the land of Egypt. Whatever the event is that the pyramids symbolize, it antedates the time of Moses by a very great period, more than a thousand years. The papyri Ipuwer and Nefer describe times of tremendous upheaval and devastation in Egypt. The one of earlier date—Ipuwer—may be associated with the pyramid period. The other may describe a cataclysm in Egypt that corresponds to the "plagues of Egypt" at the time of the exodus in the Hebraic records.

Apparently there is no choice but to accept the orientation of the pyramids as a dating device and this would indicate the early Egyptian priesthood possessed astronomical knowledge concerning the motions of the earth which has been recovered in recent times after a lapse of thousands of years. This would not be achieved without parallel developments in other fields of knowledge and the accompanying high order of development of the arts and crafts and the cultural state of the people. No records have been found of a pre-pyramid civilization of such a high order of development. Could one have existed and its works have been wiped out so completely that not a trace remains? If so, a solution of the pyramid mystery may tell us what happened. The theory that they were the work of an irrational mind is untenable. The reigns of their several builders covered more than a century. A large aggregation of fine minds was required for the planning and the building of each, particularly the two largest of the pyramids. A single irrational mind could not have extended its sway over so long a period, nor is it likely it could control so many minds each capable of leadership. The irrational, or insignificant, reason seems to be ruled out. A natural cataclysm is the more likely explanation.

The actual reason, however, still eludes us. Ancient literature contains descriptions of many strange events, some of them of terrestrial and even cosmical significance, but we still fail to grasp the real nature of these events.

Ovid, the Roman poet of the Augustan age, transmits to us in his *Metamorphoses* the legend of a wild ride of Phaëthon across the sky and his final plunge into the ocean as his horses got out of control, causing a great conflagration. Ovid records a path through the constellations starting with the serpent Hydra, (a constellation on the equator). The name Hydra is probably an error that crept into the legend in the course of its transmission to Ovid's time. The serpent is described as hugging the pole and this is undoubtedly the serpent of the constellation Draco (The Dragon) which extends more than halfway around

and is close to the pole. If this is substituted in Ovid's story the path of Phaëthon becomes a straight line across the skies from north to south. Phaëthon, in mythology, is the son of the sun, or in other words a small sun, perhaps a mass ejected from the sun, as some scientists believe the moon was split from the earth. The myth of Phaëthon, then, becomes the story of a shining body nearly as brilliant as the sun, which appeared in the northern heavens, coming out of the constellation Draco and streaking across the sky causing a conflagration on the earth. This is the constellation at which the gallery in the Great Pyramid points. The gigantic task of building the pyramid is worthy of such an inspiration. It is hard to imagine anything less being the inspiration of such an undertaking.

Concerning the actual work of building the pyramids we have no direct records. The record which goes farthest back is that which has come down to us through Herodotus, the Greek historian, who lived from about 485 to 425 B. C., and traveled extensively through the then known world. He got his information from fifteen hundred to twenty-five hundred years after the building was finished. He writes:

> Till the death of Rhampsinitus, the priests said, Egypt was excellently governed and flourished greatly; but after him Cheops succeeded to the throne and plunged into all manner of wickedness. He closed the temples and forbade the Egyptians to offer sacrifices, compelling them instead to labor, one and all, in his service.
>
> Some were required to drag blocks of stone down to the Nile from quarries in the Arabian range of hills; others received the blocks after they had been conveyed in boats across the river and drew them to the range of hills called the Libyan. A hundred thousand men labored constantly and were relieved every three months by a fresh lot.
>
> It took ten years' oppression of the people to make the causeway for the conveyance of the stones, a work not much inferior, in my judgment, to the pyramid itself. This causeway is 3,300 feet long, 60 feet wide, and in height at the highest 48 feet. It is built of polished stone and is covered with carvings of animals. To make it took ten years, as I have said—or rather to make the causeway, the works on the mound where the pyramid stands, and the underground chambers, which Cheops intended for his own use; these last were built on a sort

of an island surrounded by water introduced from the Nile by canal.

The pyramid itself was twenty years in building. It is a square, eight hundred feet each way and the height the same, built entirely of polished stone, fitted together with utmost care. The stones of which it is composed are none of them less than thirty feet in length.

The pyramid was built in steps, battlement-wise, as it is called, or, according to others, altar-wise. After laying the stones for the base, they raised the remaining stones to their places by means of machines formed of short wood planks. The first machine raised them from the ground to the top of the first step. On this there was another machine which received the stone on its arrival and conveyed it to the second step, whence a third machine advanced it still higher.

Either they had as many machines as there were steps in the pyramid or, possibly, they had but a single machine which, being easily moved, was transferred from tier to tier as the stone rose. Both accounts are given and therefore I mention both. The upper portion of the pyramid was finished first, then the middle and finally the part which was lowest and nearest the ground.

There is an inscription in Egyptian characters on the pyramid which records the quantity of radishes, onions, and garlic consumed by the laborers who constructed it and I perfectly remember that the interpreter who read the writing to me said that the money expended in this way was about sixteen hundred talents (about one hundred thousand Troy pounds). If this then is a true record, what a vast sum must have been spent on the iron tools used in the work and on the feeding and clothing of the laborers, considering the length of time the work lasted, which has already been stated, and the additional time—no small space I imagine—which must have been occupied by the quarrying of the stones, their conveyance, and the formation of the underground apartments. . . .

Chephren imitated the conduct of his predecessor and, like him, built a pyramid, which did not, however, equal the dimensions of his brothers. Of this I am certain, for I measured both of them myself. It has no subterranean apartments nor any canal from the Nile to supply it with water, as the other pyramid has. In that, the Nile water, introduced through an artificial duct, surrounds an island, where the body of Cheops is said to lie.

Chephren built his pyramid close to the great pyramid of Cheops and of the same dimensions except that he lowered the height by forty feet.* These two pyramids stand both on the same hill, an elevation not far short of one hundred feet.

* The dimensions of the three largest pyramids are:

	Length of base	*Height*
Cheops	764	480
Chephren	707	454
Mycerinus	354	218

The stones comprising the stepped internal structure of the pyramids as seen today are laid in level courses well aligned, but no one would commend the precision of the alignment. At the time Herodotus saw them, the outer covering was undoubtedly in place and they presented a smooth surface in which they may have been laid with a high order of precision. In the internal chambers today the walls are surfaced with hard polished stone and here they are finished and placed in position with the highest order of precision, indicating that the Egyptian engineer-priests of five thousand years ago were capable of making measurements achieved in no building today.

Herodotus was of the opinion that the Egyptians used iron tools in cutting and dressing the stone but it is probable that bronze tools were used. Copper was in general use long before iron became popular. Copper mines existed in the Tigris valley since very early days and it is probable that the art of alloying it with other metals had been acquired by the time the pyramids were built, and trading took place between the two areas. The limestone in the bulk of the structure is not very dense and cutting it probably did not present too difficult a job.

The nature of the derrick that was used in lifting the stones from course to course is not definitely established. The facing stones which Herodotus saw may have been thirty feet long; we have no other evidence than his word on this point. The internal stones, however, are of much smaller size. They are of uniform size so far as the thickness of the course is concerned, about two feet. Raising the stones as thick as the courses, therefore, was not a very difficult task, and likewise their transportation along the causeway from the river to the first course. Pulling them by ropes over a greased, polished causeway, as was done, may have been simpler than using rollers or wheeled vehicles.

In a country criss-crossed by canals and so flooded during part of the year that land is nowhere visible, except in the cities on elevated areas, wheeled vehicles would offer little convenience. They would be as useful as a canoe to the inhabitants of the

Mohave Desert. Absence of the wheel is, in the early Egyptian civilization, therefore, not a sign of lagging culture. It could have been imported from Sumeria, where it was early in use, if it had been desired.

The wheeled vehicle was brought into Egypt by the Hyksos (foreigners, in the Egyptian language) but usually referred to as the Shepherd Kings who came in through Canaan at the time the Hebrews were making their exodus from Egypt by the same peninsula. The use of the lever was highly developed at this early period in Egypt so the handling of the pyramid stones whose weight averaged less than three tons was well within lever techniques.

Many chemical and mechanical techniques were highly developed in Egypt even in the pyramid building days. The earlier name of Egypt is "Khem" and its hieroglyphic symbol is a triangular black mark indicating a pile of minerals. This is the root of the modern word "chemical." From this it may be judged that the chemical arts had reached a high state of development. The civilizations in the Nile valley collapsed at least twice, perhaps about 1200 and 2500 B. C., because of natural cataclysms, and it may have been necessary to recover the almost vanished arts and technologies after each of these events.

Temples, such as those at Karnak, Thebes, and other parts of Egypt indicate the heights to which the building arts rose in the successive civilizations in the valley. The articles recovered from Tut-ankh-amen's tomb, with their superlative artistic values, indicate the highly developed state of the technologies that were necessary to produce such finished products.

The next civilization to arise was that of the Greeks. They took over the building arts developed by the earlier Phoenicians, Babylonians, and Egyptians. They advanced it by applying a genius for artistic effort. They did not go in for structures of tremendous dimensions and hence did not encounter engineering problems not solved earlier by their predecessors.

A couple of engineering achievements belong to this era al-

though not credited to the Greeks. They were feats of military engineering. One was the building of a canal a mile and a half long across the peninsula behind Mount Athos, in Macedonia, which is on the easternmost of three tongues of land that stretch into the Aegean Sea. This was the work of Xerxes, the Persian ruler during his war against the Greeks (483–480 B. C.). He had the canal dug wide enough to permit two of his war galleys to pass each other with the oars working. The only reason for the canal was a safeguard against being caught in a trap as happened to his father, Darius, in an earlier campaign. The army and navy that he had assembled from the six nations under his rule, as far as Egypt, was so tremendous (more than 2,600,000 men and 1,207 ships) that there should not have been the slightest danger of an effective resistance on the part of the Greeks. This was one of the precedents which established the tradition that military forces must be completely profligate with the nation's wealth in achieving their aims and must never limit themselves by reasonable judgments. Efficiency, the art of achieving maximum results with minimum expenditures, which has brought glory to the engineering profession, is a technique foreign to master military minds.

A more interesting engineering achievement by Xerxes' engineers was the bridge built across the Hellespont, the modern Dardanelles. As a matter of fact two bridges were built in succession. At the place where it was bridged the Hellespont is about as wide as the Hudson River at New York City. It was bridged by assembling two lines of boats, more than six hundred of them, arranging them abreast, lashing them together and laying a roadway on them. The story of this event is also told by Herodotus. He states:

> While these things (digging the canal) were in progress he (Xerxes) was having cables prepared for his bridges, some of papyrus (paper) and some of white flax, a business which he entrusted to the Phoenicians and the Egyptians. . . . Xerxes, after this made preparations to advance to Abydos, where the bridge across the Hellespont from Asia

to Europe had just been finished. . . . Toward this the men to whom the business was assigned carried out a double bridge from Abydos, and while the Phoenicians constructed one line with cables of white flax, the Egyptians in the other used ropes of papyrus. Now it is nearly a mile across from Abydos to the opposite coast. When the channel had been bridged successfully a great storm arose and broke the whole work to pieces destroying all that had been done.

THE OVERSEERS in charge of the work lost their heads and a new set of master builders were set to work to build the bridge again. Herodotus continues:

They joined together triremes and penteconters (boats with three and five tiers of oarsmen), 360 to support the bridge on the side of the Euxine Sea and 314 to sustain the other; these they place at right angles to the sea and in the direction of the current of the Hellespont, thus relieving the tension of the shore cables. Having joined the vessels they moored them with anchors of unusual size, that the vessels of the bridge towards the Euxine might resist the winds which blow from within the straits and that those of the more western part facing the Aegean might withstand the winds which set in from the south and southeast.

A gap was left in the penteconters in no fewer than three places to afford a passage for such light craft as chose to enter or leave the Euxine. When all this was done, they made the cables taut from the shore by the help of wooden capstans. This time, however, instead of using the two materials separately, they assigned to each span six cables, two of white flax and four of papyrus. Both were of the same size and quality, but the flaxen cable was the heavier, weighing not less than a talent the cubit (approximately thirty-five pounds per foot).

When the bridge across the channel was thus completed, trunks of trees were sawn into planks, which were cut to the width of the bridge, laid side by side on the tightened cables, and then fastened on top. This done, brushwood was brought and arranged upon the planks, after which earth was heaped upon the brushwood and the whole trodden down into a solid mass. Lastly a bulwark was set upon on either side of the causeway of such height as to prevent the pack animals and the horses from seeing over it and taking fright at the water.

THIS BRIDGE was a success. Xerxes' two and a half million men, and unnumbered animals drawing supplies, crossed from Asia

to Macedonia in an uninterrupted stream day and night and completed the task in seven days and seven nights.

In spite of the tremendous military might of Xerxes' ancient "United Nations" force which, on the basis of numbers alone, should have been able completely to crush the Greeks, it was badly defeated, its weakness being in the lack of cohesion between its variegated units and the failure to achieve unity of action. Xerxes had many of the qualities that would make a good engineer for organizing human material but he had the wrong kind of purpose. Alexander tried the same world-conquering trick as Xerxes but worked in the opposite direction and with not much greater success.

One of Alexander's architects was a man with big ideas. He had in mind a really magnificent job of sculptural engineering, as related by Plutarch:

> This was the man (Stasierates) who had told him (Alexander) sometime before that Mount Athos in Thrace was capable of being cut into a human figure; and that, if he but had his orders, he could convert it into a statue for him, the most lasting and conspicuous in the world; a statue which should have a city with ten thousand inhabitants in his left hand, and a river that flowed into the sea with a strong current in his right. He did not, however, embrace that proposal, although at the time he busied himself with his architects in contriving and laying out even more absurd and expensive designs.

The idea of carving the Dakota mountain into a group statue of presidents appears not to have been original with our modern American sculptor. It is a pity these plans of Alexander's have not come down to us. They undoubtedly would have been quite interesting. Alexander wasn't all bad. He has been given a very bad break through having his story told by historians with Greek sympathies. He was a victim of Greek rabble-rousing, warmongering political propagandists as was his father, Philip. He gave Greece Aristotle, and the Greeks were willing to take all the credit for this first magnitude genius. In addition he endowed Aristotle with the equivalent of twenty-four million dollars for

the work of his Academy and set up a corps in his army for collecting natural history specimens for study in his museum.

Aristotle married a wealthy widow who owned a profitable sandal factory. This is one of the few indications we have that the Greeks did anything other than discuss philosophy in the Academies, politics in the Agora, and offer wisdom to the gods in the Parthenon. Somewhere there was a factory converting lumber and leather into sandals which may, or may not, have had something to do with the fact that Aristotle required his students to walk around the Academy courtyard (hence the name Peripatetics) while he taught them about the birds and the bees and to take a conservative interest in the practical things of life and not pay too much attention to that polished-pated, platter-backed, impractical philosopher Plato, who taught that there were spiritual values in life. Somewhere else in the background were silver mines that financed the "golden age."

There is a practical lesson for modern times in the example of the Greeks, who achieved so little in a constructive sense. Pericles who applied the gilt that made the golden age by supplying an architectural polish to Athenian shabbiness did so by paying for the improvements out of his own pocket. The "glory that was Greece" did not glow because of the generosity of the Greek citizens. They paid their comic commentators well and let the sculptor-philosopher Socrates, who annoyed them by exposing their ignorance, live a pauper's existence and finally fed him a cup of poison hemlock juice.

The world hasn't changed by the insertion into the picture of the radio and cheap newspapers. The Greek aristocrats despised their citizens who could do things in a productive way. Says the Greek Plutarch in his "Pericles"—"If a man applies himself to servile or mechanical employments, his industry in those things is proof of his inattention to nobler things" and, further, "For though a work may be agreeable yet esteem of the author is not the necessary consequence."

The most interesting story of engineering achievement in the

classical age is that of Archimedes, a scientist living in Syracuse, Sicily, a Greek colony. He was a genius in mechanics and mathematics, who gave us logarithms and laid the foundation for the calculus two thousand years before Leibnitz and Newton, who usually get credit for being its originators. He was born about 287 B. C., and died on the point of a Roman sword in 212 B. C. His outstanding engineering achievements belong to the period when he was over seventy years of age. The story is well told by Plutarch in his life of Marcellus, the Roman general, Plutarch (Langhorne translation. See also Plutarch's *Lives,* Loeb Classical Library, Harvard University Press, Cambridge, Mass.) states:

. . . Marcellus marched with his whole army, and camped before Syracuse. But before he attempted anything against it, he sent ambassadors with a true account of what he had done at Leontium. As this information had no effect with the Syracusans, who were entirely in the power of Hippocrates, he made his attacks both by sea and land, Appius Claudius commanding the land forces, and himself the fleet, which consisted of sixty galleys, of five banks of oars, full of all sorts of arms and missive weapons.

Besides these, he had a prodigious machine, carried upon eight galleys fastened together, with which he approached the walls, relying upon the number of his batteries, and other instruments of war, as well as his own great character. But Archimedes despised all this; and confided in the superiority of his engines; though he did not think the inventing of them an object worthy of his serious studies, but only reckoned them among the amusements of geometry. Nor had he gone so far, but at the pressing instances of King Hiero, who entreated him to turn his art from abstracted notions to matters of sense, and to make his reasonings more intelligible to the generality of mankind, applying them to the uses of common life.

The first that turned their thoughts to mechanics, a branch of knowledge which came afterwards to be so much admired, were Eudoxus and Archytas, who thus gave a variety and an agreeable turn to geometry, and confirmed certain problems by sensible experiments and the use of instruments, which could not be demonstrated in the way of theorem. That problem, for example, of two mean proportional lines, which cannot be found out geometrically, and yet are so necessary for the solution of other questions, they solved mechanically, by the assistance of certain instruments called mesolabes, taken from conic sections. But when Plato inveighed against them, with great indignation, as corrupting and debasing the excellence of

geometry, by making her descend from incorporeal and intellectual to corporeal and sensible things, and obliging her to make use of matter, which requires much manual labor, and is the object of servile trades; then mechanics were separated from geometry, and being a long time despised by the philosopher, were considered as a branch of the military art.

Be that as it may, Archimedes one day asserted to King Hiero, whose kinsman and friend he was, this proposition, that with a given power he could move any given weight whatever; nay, it is said, from the confidence he had in his demonstration, he ventured to affirm, that if there was another earth besides this we inhabit, by going into that, he would move this wherever he pleased. Hiero, full of wonder, begged of him to evince the truth of his proposition, by moving some great weight with a small power. In compliance with which, Archimedes caused one of the king's galleys to be drawn on shore with many hands and much labor; and having well manned her, and put on board her usual loading, he placed himself at a distance, and without any pains, only moving with his hand the end of a machine, which consisted of a variety of ropes and pulleys, he drew her to him in as smooth and gentle a manner as if she had been under sail. The king, quite astonished when he saw the force of his art, prevailed with Archimedes to make for him all manner of engines and machines which could be used either for attack or defense in a siege. These, however, he never made use of, the greatest part of his reign being blessed with tranquility; but they were extremely serviceable to the Syracusans on the present occasion, who with such a number of machines, had the inventor to direct them.

When the Romans attacked them, both by sea and by land, they were struck dumb with terror imagining they could not possibly resist such numerous forces and so furious an assault. But Archimedes soon began to play his engines, and they shot against the land forces all sorts of massive weapons and stones of an enormous size, with so incredible a noise and rapidity, that nothing could stand before them; they overturned and crushed whatever came in their way, and spread terrible disorder throughout the ranks. On the side towards the sea were erected vast machines, putting forth on a sudden, over the walls, huge beams with the necessary tackle, which, striking with a prodigious force on the enemy's galleys, sunk them at once; while other ships hoisted up at the prows by iron grapples or hooks like the beaks of cranes, and set on end on the stern, were plunged to the bottom of the sea; and others again by ropes and grapples, were drawn toward the shore, and after being whirled about, and dashed against the rocks that projected below the walls, were broken to pieces, and the crews perished. Very often a ship lifted high above the sea, suspended and twirling in the air, presented a most dreadful spectacle. These it swung until the men were thrown out by the violence of the motion,

and then it split against the walls, or sunk, on the engine's letting go its hold. As for the machine which Marcellus brought forward upon eight galleys, and which was called sambuca, on account of its likeness to the musical instrument of that name, whilst it was a considerable distance from the walls Archimedes discharged a stone of ten talents* weight, and after that a second and a third, all of which striking upon it with an amazing noise and force shattered and totally disjointed it.

Marcellus, in this distress, drew off his galleys as fast as possible and sent orders to the land forces to retreat likewise. He then called a council of war, in which it was resolved to come close to the walls, if it was possible, next morning before day. For Archimedes' engines, they thought, being very strong, and intended to act at a considerable distance, would then discharge themselves over their heads; and if they were pointed at them when they were so near they would have no effect. But for this Archimedes had long been prepared, having by him engines fitted to all distances, with suitable weapons and shorter beams. Besides, he had caused holes to be made in the walls, in which he placed scorpions that did not carry far but could be very fast discharged; and by these the enemy was galled, without knowing whence the weapon came.

When, therefore, the Romans were got close to the walls, undiscovered as they thought, they were welcomed with a shower of darts, and huge pieces of rocks, which fell as it were perpendicularly upon their heads; for the engines played from every quarter of the walls. This obliged them to retire; and when they were at some distance, other shafts were shot at them, in their retreat from the larger machines which made terrible havoc among them, as well as greatly damaged their shipping, without any possibility of their annoying the Syracusans in their turn. For Archimedes had placed most of his engines under cover of the walls; so that the Romans, being infinitely distressed by an invisible enemy, seemed to fight against the gods.

Marcellus, however, got off, and laughed at his own artillery-men and engineers. "Why do not we leave off contending," said he, "with this mathematical Briareus, who, sitting on the shore, and acting as it were but in jest, has shamefully baffled our naval assault; and, in striking us with such a multitude of bolts at once, exceeds even the hundred-handed giants in the fable?" And, in truth, all the rest of the Syracusans were no more than the body in the batteries of Archimedes, while he himself was the informing soul. All other weapons lay idle and unemployed; his were the only offensive and defensive arms of the city. At last the Romans were so terrified, that if they saw but a rope or a stick put over the walls they cried out that Archimedes was

* Probably the Sicilian talent of 25 pounds giving the stones a weight of 250 pounds. If it were the Roman talent, or quintal, the stones would have weighed 1,250 pounds, which seems less probable.

leveling some machine at them and turned their backs and fled. Marcellus, seeing this, gave up all thoughts of proceeding by assault, and leaving the matter to time, turned the siege into a blockade.

Yet Archimedes had such a depth of understanding, such a dignity of sentiment, and so copious a fund of mathematical knowledge, that, though in the invention of these machines he gained the reputation of a man endowed with divine, rather than human, knowledge, yet he did not vouchsafe to leave any account of them in writing. For he considered all attention to mechanics, and every art that ministers to the common uses as mean and sordid, and placed his whole delight in those intellectual speculations, which, without any relation to the necessities of life, have an intrinsic excellence arising from truth and demonstration only. Indeed, if mechanical knowledge is valuable for the curious frame and amazing power of those machines which it produces, the other infinitely excels, on account of its invincible force and conviction. And certain it is, that abstruse and profound questions in geometry are nowhere solved by a more simple process and upon clearer principles, than in the writings of Archimedes. Some ascribe this to acuteness of his genius, and others to his indefatigable industry, by which he made things that cost a great deal of pains, appear unlabored and easy. In fact, it is almost impossible, for a man, of himself, to find out the demonstration of his propositions, but as soon as he has learned it from him, he will think he could have done it without assistance; such a ready and easy way does he lead us to what he wants to prove. We are not, therefore, to reject as incredible what is related of him, that being perpetually charmed by a domestic siren, that is, his geometry, he neglected his meat and drink, and took no care of his person; that he was often carried by force to the baths, and when there, he would make mathematical figures in the ashes, and with his finger drew lines upon his body when it was anointed; so much was he transported with intellectual delights, such enthusiasm in science. And though he was the author of many curious and excellent discoveries, he is said to have desired his friends only to place on his tombstone a cylinder containing a sphere, to set down the proportions which the containing solid bears to the contained. Such was Archimedes, who exerted all his skill to defend himself and the town against the Romans.

Syracuse fell in due time, and the Romans entered and sacked it. Of the fate of Archimedes, Plutarch relates:

But what most of all afflicted Marcellus, was the unhappy fate of Archimedes; who was at the time in his study, engaged in some mathematical researches; and his mind, as well as his eye, was so intent upon his diagram, that he neither heard the tumultuous noise

of the Romans, nor perceived that the city was taken. A soldier suddenly entered his room, and ordered him to follow him to Marcellus; and Archimedes, refusing to do it until he had finished his problem, and brought his demonstration to bear, the soldier, in a passion, drew his sword and killed him.

Others say, the soldier came up to him at first with drawn sword to kill him, and Archimedes, perceiving him, begged that he would hold his hand a moment, that he might not leave his theorem imperfect; but the soldier, regarding neither him nor his theorem, laid him dead at his feet.

A third account of the matter is that, as Archimedes was carrying in a box some mathematical instruments to Marcellus, as sundials, spheres and quadrants, by which the eye might measure the magnitude of the sun, some soldiers met him, and imagining there was gold in the box, took away his life for it.

It would appear from this account that Archimedes was not at all averse to making practical applications of his knowledge, but instead greatly enjoyed doing so. The homeland Greeks had a habit of serving lethal hemlock cocktails, or exiling to the colonies, all those whose teachings were not to the liking of the political powers and hence the colonies were the scenes of practically all the scientific accomplishments for which Greece is usually given credit. In Syracuse a gentleman and a scholar could be a mechanic but the propagandizing Plutarch could not let that story get into circulation in Athens and its environs.

As the Greek power decayed, the Roman power rose. The Romans were very much better technicians and engineers than the Greeks but they went to the opposite extreme. They cared little for the scientific principles of technology but were intensely interested in their applications for practical purposes. We find the Romans, therefore, excellent builders, many of their structures still remaining. Except for fragmentary bits the only story of their engineering accomplishments comes down to us through Vitruvius, the Augustan age architect. His *Architecture* is well worth reading. It is interesting to note how he described the nature and properties of materials by using the four, then known, elements—hot—cold—wet—dry. The

aqueducts, bringing water into Rome from a variety of directions from the surrounding hills, were a magnificent piece of engineering. We do not have a story of their building but we do have a description of them in Frontinus' *Aqueducts of Rome.* Frontinus, a soldier, was given a job that we would call today "water commissioner." He found a lot of crooks among the influential citizens of Rome. Water was sold to the citizens on the basis of the amount that would flow through a circular orifice of a given size. Clever citizens changed the shape of the hole to that of a circumscribed square having the same side as the diameter of the circle. When some of them got away with that, they considered this gave them the right to change the hole back to a circular shape but with the diameter of the circle equal to the diagonal of the square. The climax of Frontinus' book is a threat that if they did not pay up he would expose the crooks.

Vitruvius described a war machine two hundred fifty feet high designed to batter down the walls of besieged cities starting at the top and Caesar described a pile-bridge he built to cross the Rhine. It was built on piles diagonally braced. Its construction required ten days. Later he built a second one that was completed in three days. They contain little of novelty. There was little demand in Rome for spectacular engineering feats and this was limited to structures that would impress the population with the power and beneficence of the government and the ruling groups.

The Arabs took over the torch of technology during the first millennium and made the mistake of trying a religion-dominated imperialism. The Turks continued the mistake in the Mediterranean region after a Siberian wave in eastern Europe subsided.

Slavic and Teutonic peoples moved into Europe from the east bringing the iron age with them. Their military leaders became their civil governors and they established an agricultural

civilization. They, particularly the Teutons, were good artificers in stone and metals and their centers of industrial activity gave rise to the growth of cities.

Once the populations achieved a relatively permanent degree of settlement a growth of population took place at an exponential rate. Its effects were not particularly apparent until the population growth curve started to bend upward about five hundred years ago and became steep about three centuries ago. Although the roots of the situation were far in the past it seemed as if an explosive growth of population began to take place at the latter period. Earlier efforts spent in bringing the environment under control were bringing productive results.

Castles of rulers which had previously been the more permanent manifestation of the building arts of the people gave way to churches, larger and more elaborate than anything mankind had previously attempted. The efforts of the people, which in earlier Mediterranean and Asiatic civilizations had been siphoned off for military projects, were expressing themselves in the building of cathedrals, churches, monasteries, and schools.

The cathedrals were the finest exemplification of the rapidly advancing engineering and building abilities of the people. The arts and sciences fostered in the monasteries overflowed to the population and found fertile ground. Techniques for producing goods were being improved, and likewise agricultural techniques, at a slow but steady rate. The vital resources of the European population were being rapidly increased. The western world was discovered.

The history of the human race that had been enacted on the shores of the Mediterranean was re-enacted on the shores of the Atlantic Ocean. Spain, France, Germany, and Britain in their time undertook in the Atlantic basin what Egypt, Babylon, Persia, Greece, and Rome tried in the Mediterranean. As empires, Spain, Britain, France, and Germany have joined the list of earlier failures. The status of the United States, democracy though it is, is a little uncertain. There is that uncomfortable

feeling that "those who live by the sword shall die by the sword." Invincible, and with glorious possibilities ahead of us, there is a strong probability that we are using the wrong blueprint for our plans and we may be in the position of Xerxes when he led the military might of his "United Nations" against Greece.

Man has made sufficient experiments in the might-makes-right technique during the past five thousand years to give us reasonably sound reasons for not doing certain things. Out of this experience and in the light of our expanding scientific knowledge and modern scholarship we can determine also the things that it would be desirable to do. Repeating the other fellow's mistakes is not the highest order of wisdom. The mistakes were made in the past on low power; their repetition on high power might be hazardous.

PART THREE

THINGS HAVE PERSONALITY

8. WONDERS OF THE MODERN WORLD

WHAT constitutes a wonder? In early days it was not too difficult to compile a list of items that excited admiration because of their size or beauty. In a world in which life was lived on a small scale anything big was a just cause for wonder, and likewise in a drab world a rare thing of beauty was a just cause for amazement. But in a world where bigness is normal and beauty is to be found everywhere what shall be the standard of wonderment?

Perhaps we can go deeper than external appearance in determining the nature of a wonder. It is not just the large size that excites admiration. In the case of the pyramids they are intrinsically large but this alone is not sufficient to explain the interest they arouse. Beholders experience a sense of mystery, a feeling that there is in them something more than the eye beholds and through them they can reach out to a larger realm of experience.

The walls of Babylon were an item in the seven wonders as listed by Herodotus. Here again the size was tremendous, but the claim to wonderment is associated with the fact that we get a thrill from contemplating the control over men, material, and natural forces involved in planning and erecting them.

The hanging gardens of Babylon were smaller than many a suburbanite's garden. The fact that the water for them was raised two hundred feet by slaves would hardly make them unique. But viewed as a grove of trees transported from a distant land to make a queen, a woman separated from her kinfolk, feel more at home, to create the situation in which she could feel in more harmonious relation to nature, we share her thrill.

The Tower of Babel was of impressive appearance but the goal

of the builders, to raise a ladder to heaven, to penetrate more deeply into the mystery of nature, is the source of the thrill.

The walls of China gain their impressiveness not so much from their size or extent but from the belief we build up that the tremendous effort put forth in building them was commensurate with the precious nature of something within, to which they were supposed to bring protection, the symbols associating the present with the traditions of a dim, mysterious past.

In the case of the temples we had beauty of design associated with the sense of the divine which invariably produces a thaumaturgic thrill.

Every wonder in all of the lists compiled at various ages have had some factor which associated them and the beholder with something beyond them and themselves, that gave a sense of expansion in power, control, or knowledge.

With this as a standard, how are we to select a list of wonders of the modern world? Just a list of the physical items on which man has labored to produce something unique or beautiful would fill a volume. A million items could be recorded. If this list were submitted to a million individuals and each was required to select the seven or seventy greatest wonders, it is likely that there would be but slight agreement among the lists.

The time, the place and circumstance has a good deal to do with our judgment as to what is the greatest wonder. If we are in the middle of the ocean aboard a modern luxury liner, that ship is the greatest wonder in the world, and if we are five thousand feet above the surface of the earth in a four-motored broadwing airplane, that flying craft is man's most wonderful achievement. Under other circumstances it could be the family motorcar, the radio, television, the telephone, the electric range, the electric light, the gas stove, the oil heater, the luxury train, a skyscraper, a bridge, a tunnel, the subway, a weekly magazine, a newspaper, a painting, a cocktail, a poem, the movies, a particular person, any person, a flower, an insect, a star, the sun, the moon, an equation, a song. It could be anything from a sunset to a steelmill.

Thanks to our scientists, engineers, and artists we are surrounded by awe-inspiring, wonder-producing objects and situations. We are surfeited by the wonders already with us, yet we eagerly reach out for every new one. They satisfy our sense of magic-hunger, the reaching for the something of infinite power and strength that seems to be in us and around us but which we can't grasp. Let a scientist make a discovery, or an engineer throw a magnificent bridge across a great river, or a painter achieve a subtle conception on canvas and we feel that he has grasped something of that which we seek and we want to share the greater world he lives in.

No average size book could adequately present the achievements of modern engineering in its various fields. A review of engineering developments indicates the rapid changes that have taken place in the course of modern technical development during a century and a half.

Up to about 1800 all engineering was civil engineering with principal interest centered on roads, canals, dams, docks, and buildings.

Modern power engineering started in 1807 when Robert Fulton demonstrated on the Hudson River the practical and business aspects of steam power transportation. Stationary steam power projects enjoyed a parallel development.

In 1865 the era of railroad expansion started and with it came the demand for substantial bridges and for tunnels.

Electrical engineering got under way about 1880 as the Edison system made electric light and power available; Bell's telephone system got under way, and electric cars were used for passenger transportation. Steel ships came into use.

1900 saw mechanical engineering undergo a wave of expansion with the advent of the automobile.

1910 saw the coming of labor-saving devices and mass production machinery in industry.

1920 marked the advent of radio broadcasting and the slow rise of aeronautical engineering.

1930 marked the rise of chemical engineering and the expansion of synthetics.

1940 saw electronics engineering become a major factor.

1950 begins the era of atomic engineering, the era of nuclear energy.

In each of the fields mentioned there are hosts of achievements that could be hailed as wonders but each accomplishment is dwarfed by the multiplicity of other contenders for first honors.

There is really just one wonder of the modern world and that is the sense of unification of all nature in a single pattern which we can understand, in part, and to which we can relate ourselves and all other individuals.

The multiplicity of machines loses its confusion and we begin to sense behind them the manifestation of the single entity, energy, which the engineers are harnessing to our will. Our body processes are shown to us as a mechanism on the highest level, for consuming energy to manifest that supreme phenomenon, life, in which we resonate with that larger pattern of the cosmos.

9. SEEKING THE DESIGN FOR LIFE

IT IS generally assumed that the human race is achieving a pattern of progress. If all our varied activities, some forward, some backward, were balanced against each other and the net result in all ages integrated we would find a residual amount of something that we call progress. The magnitude of this residue varies greatly from year to year, from decade to decade and century to century. Any positive accumulation that may have been in existence at the beginning of the present century has, undoubtedly, been wiped out in the interim. Despite valuable forward-looking contributions of great magnitude we have, nevertheless, been creating, in recent decades, an ever increasing negative balance. Back and forth, hither and yon, from post to pillar, we have moved, sometimes with great energy and at high velocity, but always bounding from unsolved problems into unseen predicaments. We have not shown the slightest observable trace of any conscious knowledge of the direction in which the arrow of progress points, or of the proper path on which to proceed under a long term program.

The journey most difficult to plan is one in which we don't know where we are going. If we are, by intent, going nowhere in particular we have the privilege of starting in any direction and going as far as we wish. Our freedom of choice is unlimited. We can change direction at any point and the change can be justified. If we inject into the situation an intention of moving in the direction of progress, but no one can tell us how to select the right direction, we are justified, as before, in choosing any course and changing the course for any rational reason. If, however, we declare a purpose of moving in the direction of progress we are under a responsibility to determine if any particular course has

produced results more beneficial than those resulting from other courses.

The activities of a sufficiently large community are likely to be so varied that if each activity could be given a value and an arrow assigned to it pointing in some determined direction between progress and regression it is likely that the whole dial of direction would be covered with arrows. Some would be long, indicating large values, and some short, indicating small values. Despite the apparent complexities, a mathematician would have no difficulties whatever in adding up these arrows, both in their length and direction values, and he could give a single arrow, of a particular length and direction, as the answer.

If such a charting of all activities were made it would be a simple matter to determine the particular activities which are responsible for the net result being in the direction of progress and those aimed in the opposite direction which are working against progress. The course of action that should be taken after the direction of progress is determined becomes obvious. The freedom of choice of courses then, however, becomes extremely limited. Has something of value been lost when the wide choice of courses has been eliminated and action must be directed within a narrow range? No. Freedom of choice was of value only when, and because, we lacked knowledge of the direction of progress. Once the correct direction has been determined a choice of any other direction not only has no value in contributing to progress but is a hindrance to progress.

Making such a chart of communities would not be an impossible task. Errors would be made in the length and direction of each arrow but a useful degree of accuracy would be achieved. We would know within a useful limit of error the activities that are contributing the greatest positive and negative values. Such a chart would provide a representation of the vitalistic form, or design, into which a community shapes itself. We cannot see the shape of the intangible body of a community by casual inspection, but neither can we determine the shape of the earth by

a local look. It is, however, the intangible pattern of a community that shapes its material aspects.

Every material thing that exists must have a form. What decides the shape of an object? In nature the operating forces, and the properties of the material operated on, determine form. A whirlpool in water and a hurricane in air express in their fluid spiraling design the impressed forces and the properties of the medium in which they are operating. A drop of water falling through the air expresses by its shape the state of equilibrium attained when gravitational pull, air resistance, surface tension, and the cohesion between molecules are balanced against each other. A wave, with a plume of foam capping its curved surfaces of dynamic beauty as it rushes shoreward to the beach, is at every instant in equilibrium with forces and conditions. A shooting star, as it flashes in incandescent brilliance across the sky, is in equilibrium with forces of gravitational pull, electrical conditions in the ionosphere, and the properties of its own substance, just as was the raindrop, but the results are different. Iron filings sprinkled on a paper under which a magnet is placed arrange themselves in equilibrium with the field of the magnet, delineating its field of force like a whirl of static energy. The invisible lines of force, in turn, are in equilibrium with the conditions within the atoms of the iron that brought them into existence, a condition which gives us a clue to the nature of the forces within the atom.

Form and design in nature, are, therefore, not due to chance but are phases of an unending series of cause and effect relationships that give us useful information about the properties of a substance and the forces to which it is subjected. All three—form, properties, and forces—are inextricably interlinked. Properties of substances are usually a function of their energy states. Water, for example, in its lowest energy, is ice and, in its highest energy state, is steam or vapor. Steel at very high temperatures is liquid but at low temperatures a rigid solid. Magnesium at high temperatures is a vapor but at low temperatures will condense to beautiful cubical crystals whose form is related to the energy content of

its atoms—the number of nuclear particles and electrons they contain.

Nature is, therefore, our first architect. She established the science of forms and design. Never is one of her designs lacking in purpose and they are always functional. Almost invariably the results are aesthetically satisfactory from some aspect. Aesthetic aspects, however, appear to be an uncalculated by-product resulting from proper purpose and function. Sometimes, however, recognition of beauty is a matter of scale. A pile of white powder may not present aspects of exceptional aesthetic value, but when some grains of this powder are viewed under the microscope they are found to be extremely minute skeletons of diatoms more beautiful than the work of any jewelry designer.

Our most beautiful bridges are pictures in steel of the stresses developing in the roadway and purposeful parts of the bridge. No non-functional parts are added. Nature uses the fewest necessary parts, or amounts of material or energy, in her operations but never less than enough in her normal operations. She may appear to be a spendthrift in some situations, but a better understanding of what is taking place usually reveals an ingenious economy in her operations.

The airplane has taken on a unique contour in the processes of improvement. There is but slight resemblance between the original airplanes with their almost flat wings of rectangular area and double-decked construction and the present thick-wing monoplane with elongated tear-drop fuselage and general streamlined contour. Engineers may take credit for having created this design but it was inherent in the dynamics of a body moving through the air with self-supporting members experiencing a minimum of drag. It is not just a static design but one that is dependent upon the amount of energy expended, the weight to be lifted, and the speed to be attained. Vary any one of the factors and a new contour is indicated. This contour was not created on the drafting tables but by the slip stream of the air as the plane moved.

Nature is the great teacher in matters of design but even the master teachers will advise, "Do as I say, not as I do," and, "Follow the light, not the lighter." It is possible to go very much astray by adopting a particular design from nature which was developed for a particular situation while losing sight of the underlying fundamental principles that are applicable to all situations. In the application of nature's principles of design, it is necessary to have a feeling for forces, a sense of substance and a faculty for capturing rhythms that may be functioning best in the subconscious realm.

An electron shooting through space is surrounded by waves which are non-existent when it is standing still. The amplitude of the waves, their wave length, grows smaller as the velocity of the electron increases and in its reactions the waves become the dominating factor, the electron acts like a packet of waves while its primary nature as a particle of matter almost disappears. This appears very abstract but utilization of the principle made possible the electron microscope which extended our range of vision many octaves into the sub-microscopic realm. At the other extreme the sun appears to be surrounded by a zonal structure, not radically different from that surrounding the electron, and in the nodes of these zones are the orbits of the planets, although the equation for the electron waves will not give the longer planetary distance waves when applied to the sun.

We have not developed detectors or measuring rods to be applied to objects in the intervening size scale but to the understanding mind it is not difficult to become consciously aware of the rhythms and zones of individuals, buildings, communities, cities, and nations. They are all parts of the energetics of nature and when understood give us the basis of dynamic design as contrasted with static structural anatomy which has been the commonest motif in architectural planning.

Social and political planning should be directly linked to nature and based on the finest example of co-operative design, that which is used in the human organism, and the principles of

cosmic harmony which the human mind has derived from its study of the universe. These principles of harmony and co-operation have been avoided with resulting social, economic, and political instability. The disheartening feature is that each few generations the same mistakes are repeated. There is a taboo against stating the truth concerning political failures. As a result Washington today is making the same mistakes that Julius Caesar made two thousand years ago.

Progress in social design cannot be expected to equal the advancement in other fields of design in which advantage can be gained from study of previous failures. Civic design, or city planning, will for this reason lag far behind the best examples of architectural design, and these still farther behind the more individualistic artistic efforts as in painting and sculpture. Creative effort in the fields of art, science, philosophy, or literature will not thrive as a national characteristic where there is a lack of satisfactory social design underlying the national life.

The Romans failed to acquire any basic, sound system of social design despite the fact that they despoiled the ancient world of its art treasures and made slaves of all artists, architects, technicians, writers, philosophers, engineers, and all others who possessed the ability to practice the arts of civilization. The Roman masters were capable of appreciating to only the slightest degree aesthetic excellence in a structure or artistic composition of any kind. If a temple, forum, amphitheatre, or a palace was massive and impressive and well supplied with architectural gadgets they were well satisfied. During the kingdom and the several centuries of what the Romans called the republic, but which was just a military slave-holding oligarchy, the city of Rome was nothing but a walled-in, tottering, brick slum without even a respectable palace for its oligarchs. Seldom a week went by which did not see the collapse of one, or a row, of four or five story brick slum-tenements. Invading Gauls in the early life of the republic and Nero during the empire were world benefactors for having burned the slave-yard that was masquerading as a city.

Augustus bragged that he found Rome a brick city and transformed it into a city of marble. It would be more truthful to say he put a marble veneer on the public buildings around the various campi, or public squares, and required the wealthy military oligarchs to build palaces along the Tiber in keeping with his public works program. Even in Augustus, however, there was not the slightest trace of a Pericles.

When the Romans made the countries of the known world into Roman provinces they commemorated their victories and control by a very extensive building program in which temples and official buildings were erected at the expense of the conquered peoples. They were a brutal, bloodthirsty crew without the slightest appreciation of the sanctity of human life. The only appreciation they manifested was that of the synthetic sanctity of their system of law which guaranteed their property and wealth regardless of the means by which it was gained.

Engineers in the early cultures had a single purpose in life—to produce mechanisms, munitions, and the materials of military might so that the rulers could conquer other countries, and if fates were unkind that the armamentaria could be used in defense. Foreign conquest was not the only task of rulers; it was necessary also for them to keep their own people in a state of subjection. This called for more subtle measures. In this task the architect was the important person. Home populations were kept impressed by palaces, temples, and public works undertaken by the ruler. The greater the magnificence and magnitude of the palaces and temples, the greater the power of the ruler before whom the people were supposed to cower. This was a very ancient practice. The Roman leaders, following the collapse of their alleged republic and the setting up of the empire, had greater need of this technique than any country which ever existed, and they used it to the fullest extent—that was "the grandeur that was Rome," but it was unavailing in stemming the collapse.

Continuous campaigns of military conquest in the closing centuries of the pre-Christian era had impoverished the conquer-

ing and the conquered people alike. Rome merely rode the down-rushing wave of a declining Mediterranean civilization—of cultures bled white of material and human resources. To the north, in Europe, was another type of civilization maintained by the German tribes against whom Caesar's legions had not made much progress in a military way, enough, however, to enable the Romans to establish trading. Through this Rome was supplied with the armamentaria of its industrial and military iron age which supplanted the copper age materials that had come to it from the east. The starved, disheartened slaves and workers of Rome and its dominions were no match for the virile population of the Germanic area which produced soldiers who were finer physical specimens than those in the Roman legions, and whom the Roman emperors preferred for their bodyguards in Rome. The feudal government under which the Germanic tribes lived was military in nature and was far from ideal, but it was vastly better than the slave state of Rome. Their country was largely undeveloped and they were so busy bringing the region under cultivation and discovering and developing its resources that they had little time or effort to spare for foreign adventures. In time some of their leaders developed the urge for expansion and traveled southward. They did not conquer Rome; they paid a friendly visit and administered last aid to a collapsing conglomeration of economic, political, social, and military chaos. There was little they could do for the expiring band of barbarians that called itself Rome; the Romans had done too much for themselves.

Under the sylvan civilization of the Gallic and Germanic people, culture had a chance for a rebirth. History was abolished, that is, what has been called history—records of predatory conquest and empire building. Such activity was all right for the barbaric Romans, but the civilized Europeans found it, and slave holding, equally repugnant. Efforts have been made to inject a history into the era of peace in Europe that followed the self-exterminating cure of Mediterranean militarism but they have

not been very successful. Traditions of the original military form of government in Europe remained during the development of the civil structure. Some aberrant groups, atypical vestigal anachronisms, carrying the Roman virus in a latent state, flared into activity on a few infrequent occasions without doing much damage but this Roman adulteration manifested a much more dangerous development in a slow, recessive growth which was serious enough to become history many centuries later.

Balancing this curse came a beneficence from the Roman exposure to Christianity. Its theology was neither important nor significant but its emphasis, in its original state, on the transcendental value of human life and spiritual concepts made a most harmonious juncture with the philosophy of the European peoples. This was the reverse of the situation in Rome. The Roman ruling caste was taught, "You can value the work without esteeming the worker," and they thoroughly despised workers of all kinds. Architect, engineer, artist, and artisan were worthy only of slave classification. Vitruvius, the only Roman architect who has left any record behind him, in each successive dedication of his books was continuously licking the boots of Augustus in the most approved Ciceronian tail-lifting manner. There was no cause for surprise, therefore, in the wildfire spread of Christianity among the suppressed humanity of Rome. The Christians placed a value on their own lives and aspirations, and the lives and hopes of others, while their rulers placed a value only on the goods produced.

The Romans were unable to work mines on the Italian Peninsula for any extended length of time because the intolerable conditions they imposed on the workers led quickly to rebellious uprisings. Minerals from the provinces, from the conquered countries, were, therefore, an essential factor in their economy. This situation can be contrasted with that among the Europeans to the north where the artisans were honored for their accomplishments, and miners were given the highest professional standing in the community. To this European tradition of the ele-

vated status of the worker came Christianity linking man directly with the Deity and giving him full participating citizenship in the church.

With increase in population in Europe and growth of all phases of activity, government, church, and industry, there developed some competition due to overlapping patterns of service. Relations were fundamentally harmonious. The task which all faced was solution of the problem of producing enough food and materials, through labor applied to natural resources, to provide sustenance, shelter, and tools for a fair standard of living plus an additional amount that might be spared for cultural advancement. The development of the industrial arts led to the establishment and growth of cities. In these cities government expressed itself by the building of walls as a symbol of its function of protection; the arts expressed themselves in the building and furnishing of homes and the church manifested its function in the building of churches and monasteries in which, in addition to spiritual activities, the acquisition and dissemination of knowledge was carried on. It is not surprising that the institution which fostered technical and artistic culture should have the highest development of these arts expressed in the structures that symbolized its activities and its growing power; and it is for this reason that the development of this long era of peace should have its fruition in the so-called Gothic cathedrals of the Middle Ages. The ducal and feudal palaces symbolic of government were insignificant and puny things in comparison.

It is not correct to call the architectural development now known as Gothic by that name. Germanic or Teutonic would be better but still incorrect for it was as much, or perhaps more, Celtic than Teutonic. It was European, or more particularly western European.

It was about the beginning of the second millennium that the monumental churches and cathedrals began to make their appearance in western Europe. They did not appear suddenly; their antecedents went through a normal course of development

in which the techniques of design and construction were worked out. The cathedrals were prayers in stone by imaginative supplicators of the Almighty. The same kind of a prayer was uttered four thousand years earlier in ancient Babylon when the ziggurat raised its serried steps as high as many a European steeple. What a difference, however, in the manner in which the two prayers were expressed! In the earlier construction there was a ramp rising on the flanks of the pyramid-shaped pile up which the priests, and astronomical observers, climbed every day to perform their rites. In the European cathedrals the spires make the journey symbolically, and the chimes in them speak louder and more harmoniously than any stentorian priest.

Nothing comparable to the European cathedral, from a structural viewpoint, was developed in any earlier civilization. The emotional expression crystallized in them was not earlier attainable on a community scale. Without community co-operation they could not have been brought into existence. They were not something that could be ordered by a political dictator and produced by slave labor. The masons who carved the stones and placed them on the rising edifice were fired with as much zeal as the ecclesiast-architect who designed them. The courage of the designers who embarked on the novelties in each successive structure was of the highest order. Occasionally the new venture collapsed.

The cathedrals were monuments to the position of dominance which was held by the church in the life of the European communities, but they had utilitarian aspects in addition to their use for ecclesiastical routine. Richly supplied with carvings, they became, by the subjects depicted, textbooks of church and civil history, and of agricultural and industrial arts, in an age that preceded the production of printed books. Carvings were more widely understood than the written languages. They were also the centers of guidance for the political rulers.

Increased productivity of the agricultural and industrial arts in Europe was made possible by a steadily expanding rise in

population which, once started, rose more rapidly than the rate at which production was increasing, causing economic tensions among various areas. Industrial developments were beginning to take on a new aspect as well as a new enlarged magnitude which brought into existence densely populated and rapidly growing cities whose political power was important. Exploration opened up new lands and their population and development were made possible by the increase in European populations. The spirit of empire flared anew and all European powers competed for a share of the new lands. Renaissance Roman ruthlessness could not be handicapped by ethical concepts sponsored by the churchmen, and the rebelling rulers found their program facilitated by an infection of the old Roman virus for temporal rule with which some of the churchmen, too, became inoculated. The increase in population made more individuals available for scholarly and higher technological pursuits. Industry as it grew could attract the technicians. Statesmen required the services of the engineers and found they could seize some of the prestige formerly held exclusively by the church by becoming patrons of scholars. Statesmen, becoming aware for the first time of the work of the scholars, believed that they, through their patronage, brought it into existence. The increasing use of the art of printing, making possible the quick duplication of the rare handwritten books, coming about the same time, confirmed them in their beliefs that they had brought about a rebirth of knowledge. The so-called Renaissance was characterized by a quantitative, not a qualitative, change in knowledge, although there were changes in viewpoints that resulted from the wider dispersion of knowledge.

The normal divergence in interpretations of religious and philosophical theorems within the church expanded to a wider spectrum as the numbers of members and scholars within the church increased. The extremes in any direction exhibited decreasing cohesion to the median conservative groups and as tension among states, church, and industry became greater it was

not difficult to split off extreme groups which formed alliances with local statesmen. Some groups isolated themselves for development of universities and independent schools. A formula that would keep all groups working in a harmoniously related pattern had not been achieved. In the political field the feudal system developed as many diverging factors as the church with the same result. Industrial and military oligarchies came into existence as antidotes to equally extreme cults of the ancient communism that appeared under various names.

Steam power and machine methods of production set loose in communities of all sizes, from villages to nations, forces which the unstabilized structures of these communities were inadequate to handle. The industrial and political powers were vying for the leadership which no longer was posited in the church. When necessary, in order to prevent the rise of any third factor, they united their forces but otherwise they fought for leadership and dominant power. It was an uphill fight for the industrial powers, but the electrical age and mass production increased their power and prestige within nations more rapidly than the power and prestige of the political powers expanded. Now it became the wise move for the political powers to make common cause with the industrial forces. It became obvious to astute political leaders that industrial mass production methods were the most effective methods for creating military power. The entire national productive system became a prolific arsenal in all industrial countries.

In all the changes which have taken place in the past nearly two thousand years, a dynamic pattern is evolving identical with the pattern that evolved in the approximate one thousand years of Roman history and this probably was but a repetition of the pattern that unfolded and collapsed in like fashion in Sumeria, Carthage, Egypt, Assyria, Babylon, and other ancient civilizations.

Rulers in the past have never possessed the faintest glimmer of the idea of community biology, nor are our rulers today

blessed with much greater insight. Communities have their growth and physiologic functions just as do individual human bodies. They also have diseases and disorders, most of them self-induced, just as in our experience with human individuals. In the past quarter of a century, for example, a contagion among nations has resulted in an epidemic of the manic-depressive psychosis which is characterized in its extreme manifestations by alternate periods of murderous aggression and suicidal depression. The economic analogue of fatty degeneration of the tissues is too obvious to require elaboration. Such little insight into community biology as our ruling groups possess is viciously misapplied. They know, for example, that a nation, like an individual, can be thrown into a state of hysteria; likewise, that a fear reaction, leading to the release of the animalizing adrenal gland cycle can be started by judiciously used propaganda, and that when this cycle is operating neither an individual nor a nation is able to engage in rational conscious thinking and can be led into situations and actions against which the people would rebel to their last ounce of power if they were permitted to remain in their normal rational thinking states.

Such situations are community disease states. A medical man would call them syndromes and a syndrome is a pattern of symptoms. To the doctor treating an individual, a pattern of symptoms conveys a picture of structural or functional abnormalities in the body. For the great majority of such situations there are available preventative or remedial treatments. Partly by the use of such treatments the average life span has been vastly extended. Life expectancy at birth for the average individual today is 67 years; in Rome, it was 30 years. More than 75 per cent of the improvement has been brought about in recent centuries. A similar approach to problems of community biology would provide a longer life span for a national or continental culture. This is a problem in human engineering, and the prevailing Roman rule technique is definitely unuseful in this field.

By changing the time scale of history so that its panorama

passes before our eyes in quick review we can see Rome and Europe go through two identical cycles of evolution. In specific aspects there are exact parallels between the two civilizations. Rome established its power on a materialistic doctrine of property rights and made a complete failure of the task of administering its dominion for the welfare of its own and other governed people. Christianity offered a philosophy based on the completely opposed doctrine that human values and spiritual concepts were the important factors in a civilization. The doctrine was offered to the submerged elements of the population and spread through them like a forest fire. Efforts were made to prevent its spread, and to exterminate it, by slaughtering its leaders and members, sacrificing them at public festivals for the entertainment of the ruling cult and as a warning to the Christians. In spite of such treatment Christianity spread and prospered while the cult of rule for the protection of property rights decayed. This is not evidence that material assets are necessarily a toxic factor, or that spiritual values are the only safe basis for a civilization. It does not mean that all of the Roman ruling class were completely vicious and incompetent and all the Christians entirely virtuous and competent to rule the world successfully. A merger of the two preserving the best factors of each, if effected in time, would have provided a powerful combination for stabilizing civilization.

Today, as in Rome, we have a civilization in which respect for material aspects and property rights is again the dominant factor in the ruling classes. Again today, paralleling the emergence of Christianity in Rome, a doctrine is being preached to the economically submerged groups and again it is spreading like wildfire. Our modern Nero is the "Un-American Activities Committee" in the Congress plus the propaganda powers of the entire governmental system. In spite of the persecutions, mislabeled patriotic activities, the doctrine of Communism spreads. It is, very definitely, thriving on persecution. This does not mean that everything in our present civilization is wrong and

vicious and that everything the Communists stand for is virtuous and desirable. The failure of Communism properly to dignify the individual will prevent its ultimate, and even temporary, success. Its growth, however, is evidence that our present system is not perfect, that increasing numbers of people are convinced that it is not working out for their welfare, despite alternations in political parties, in unsuccessful efforts to bring about improvements, and that some fundamental changes are desirable in the philosophy under which each party operates. Stubborn and stupid failure of the two major political parties, now united to resist change, may result in inflicting a Communistic regime on the entire world with unfortunate results. The Roman Empire is again tottering. We observe the surprising phenomenon that Christianity which achieved its power by taking the burden of the socially and economically submerged elements is now in the relative position of the Roman rulers in opposing the new rising of suppressed elements.

Clever statesmanship could very easily bring progressive changes to our present social and economic structures which would be so universally beneficial that Communism would be stopped in its tracks and caused to wither for lack of support. Revolutionary changes are not required. The principal requirement is an experience in illumination, on the part of both leaders and people, which would come with a scientific revelation of the biological and spiritual nature of the community and the individual, and a knowledge of social chemistry and economic physics. If this were achieved, our communities, international, national, and domestic, would redesign themselves. A magic-making Messiah, with transcendental powers, is not required; every man would be his own Messiah. The faculty for conforming to the best organizational structure is inherent in the individual and will manifest itself unless overpowering forces are imposed on him. The individual who knows the truth presents a far greater probability of doing the right thing than one kept in ignorance of the facts.

So far as basic, factual knowledge of the nature of and control of our lives in their individual, community, national and international aspects is concerned, the vast majority of human beings are kept very much in the dark and very much misinformed. One of the techniques by which we are kept in this state of intellectual infancy is the great-good-man theory and its converse—the big-bad-man theory.

Under this theory single great men appeared at isolated times and widely separated places in history as purely happenstance phenomena, without relationship to their times or environment, and by their own unaided efforts completely changed the thought processes of the great mass of people and altered their course in history. Among such were Buddha, Jesus, Rameses, Moses, Alexander, Caesar, Aristotle, Charlemagne, Luther, Washington, Lincoln.

It may be thought a rather peculiar coincidence, however—if great men actually did appear in such purely happenstance fashion—that Lincoln did not appear in slave-holding Rome, that Buddha did not appear among the Tartars of Genghis Khan; that Mahomet did not appear among the placid Chinese, and Moses didn't land on the Plymouth Rock—to cite just a few suggestive contrasts.

There are, have been, and will continue to be great men, but they have not appeared spontaneously and have not appeared without relationship to their community and its problems. If we were given the complete picture of the situations which have produced the few, isolated, great men about whom we hear so much, we would find that the conditions responsible for their appearance existed long before their coming and contained men of almost as great magnitude, and so on down the scale to the great number of average caliber and less, all of whom were just as essential to the situation as the single great-man by whom it is symbolized.

By shifting entire credit to the single great-man, he can be glamorized and idealized in any way desired and there can be

associated with him, as effect-producing virtues, all the characteristics and ideas to which it is desired to give support, and which it is desired to have all individuals emulate. The great-man as thus glamorized and idealized may exhibit only the slightest degree of correspondence with reality. This is a very useful, subtle, and effective process for shaping the ideals of a people into forms which permit desired responses.

Most important, however, is the fact that the great-man theory sanctifies and makes orthodox the control of a nation at each successive period by a single individual who, with available techniques for control of public information and education, can be glamorized and idealized as a great man who is creating a new era for the people. The spontaneous great-man does not have to have his greatness explained on rational grounds nor must there be an explanation of how his particular acts will lead to the excellent results associated with the rule of great men, since the great-man is supposed to appear in spontaneous, unexplainable fashion.

Credit for the contribution by the great mass of the people to the creation of progress and new eras is completely suppressed under the great-man theory. They are made to appear entirely in the role of beneficiaries, as recipients of the fruits of the genius of the great-man, and not at all as the primary creators of the advances of which the great-man is merely the administrator. Since the great mass of people are thus relegated to the status of recipients of benefits, in which capacity they should be very humble, they must not expect anything resembling a controlling voice over the actions of the great-man.

The converse of the great-man theory is the big-bad-man theory; the one is the inescapable complement of the other. If any group, national or other form, is developing characteristics considered unfavorable to the purposes of a great man, or if the group is developing in exactly the same way as the group under the great-man (but perhaps at a faster rate under its great-man) so that our great-man considers it a dangerous com-

petitor, he then decides to smash the power of the competing group, but in order to do so with an appearance of sanctification for his action and to make his purpose appear a moral one, he must transform the competing great-man in a big-bad-man (using the same propaganda mechanism that transformed him into a great-man). It then becomes a moral responsibility for the great-man to use all the resources of his community to smash the big-bad-man (and the community of which he was an integrated part) under the pretext of releasing his community from his machinations.

The alternative to the great-man and the big-bad-man theory is to achieve a more realistic picture of the community structure, in which the really great men are the products of service to the people on a program that will meet real needs, and to provide more widely distributed controls that the community may receive the benefit of the guiding and intellectual powers of all of its members possessing abilities which would enable them to make real contributions. It should be required that names and labels match reality. A democracy, under the great-man theory, is one in name only and remains a monarchy despite a more rapid rate and different technique for changing the figurehead, and state setting which, though operating, are rendered non-functional.

Recognition of a more realistic pattern of community structure and the desirability of conforming to naturalistic patterns inherent in the nature of man and his characteristics in community relationships, plus a sincere regard for truth—the whole truth—and the competence of particular individuals to voice the truth—would result in the creation of a far more efficient, stabilized, and powerful community. Since the purposes of such a community would never be inconsistent with the fundamental nature of the individual or his community pattern (nor of other communities similarly established), it would be possible under such conditions for the wise man and the good man to occupy the functional position of great-man.

There exists throughout the cosmos a universal pattern of which everything that exists is a part, the far flung external galaxies, our own universe, the solar system, nations, states, societies, the earth, men, animals, plants, atoms, and fundamental particles of matter. The pattern is not static, it is dynamic and super-charged with energy. This pattern contains the basic principle of all form and design. Things out of harmony with it are destroyed by its forces; things in harmony with it grow and prosper through the same forces. Like all dynamic, vibrant, things it is full of harmonics, above and below its fundamental note so that there is a tremendous range of frequencies and wave lengths with which we can get in tune. A vibrant body in tune with its environment can go into an oscillating state and extract energy from the environment to maintain or direct its activities. This is the process by which radio receives programs out of the air. If the energy so extracted is not usefully applied, it can react to bring about the destruction of the body into which the vibrating energy is fed—a principle well known to engineers. It is like a motor which when operated at normal speeds renders a very useful service but which can be raced at so high a speed that it brings about its own destruction.

Man-made structures can be given design characteristics in mass, form, size, and energy responses, so that they possess aesthetic values, which is our rule-of-thumb way of deciding whether or not they are in harmony with the universal pattern whose blueprint we have not seen but which we know through subconscious sources has a real existence. Living things, through their continued manifestation of life phenomena, are demonstrating the existence within their structure of conditions in harmony with the universal cosmic pattern. Their biological design in each case may indicate that they are resonating to particular low energy frequencies, or to high frequencies. As we learn to read the vitalistic blueprints, we will be able to determine from their biological design the part of the universal energy spectrum with which they are resonating.

When scientists were pushing their investigation of radio waves into ever higher frequencies, to learn the properties of the new wave-lengths, an interesting situation involving what appeared to be a very profound mystery developed in Bell Telephone Laboratories. A circuit was set up to investigate the region from ten meters down to a fraction of a meter. As it was tuned to the various wave-lengths in small steps the various instruments were read, their indications recorded and points plotted on charts for drawing curves of the performance. The dots on the charts indicated nice smooth curves until a point a little above the three meters wave-length was reached. At this point the needle of the ammeter, indicating the amount of current consumed, took a sudden jump to an abnormally high value showing that something unusual had taken place. As the circuit was tuned to slightly shorter wave-lengths, the charted points went back to the normal curves and stayed on the normal range for the remainder of the test. The experiment was repeated and at the same point in each test came the reading on the instruments indicating that a relatively enormous increase in the amount of energy was being radiated into space. It looked as if, at this wave-length, space had become highly absorbent and could drink in great amounts of energy, figuratively, as if there were a hole in space into which the current from the circuit was leaking. The conditions of the experiment were changed in a variety of ways but always the mysterious adsorption at about three meters. The solution of the mystery was finally achieved, and it proved to be a very simple one. There weren't any holes in space, or any changes in the property of space, at three meters. It merely happened that the operator had tuned the circuit so that it was in resonance with his own body; the radio circuit was radiating the energy into space and when the energy was of just the right frequency the operator's body started to absorb it. A man five feet six inches tall had an electrical wave-length of about ten feet, approximately three meters.

This is merely an analogy and does not mean that the universal

pattern is powerized in radio waves, for it may express itself in some entirely different form of energy. Vital phenomena of life may manifest themselves on frequencies of vastly different values, or in activities very different from the familiar vibratory activities. The analogy, however, is capable of wide application.

Communities possess design characteristics even more complex than a cathedral or a bridge, and this design, structural and functional, will determine whether it possesses survival value and to what extent, or whether the operation of natural forces will cause it to disintegrate from one form and be resynthesized into another design more resonant with the universal pattern. It is not necessary to know in a scientific way all the characteristics of the universal pattern. As a matter of fact, it is possible to make great progress with the right attitude and very little knowledge. The situation is comparable to that of a piano tuner. The piano contains an array of strings most of them of steel with a thinner copper wire wound around them, stretched tightly across an iron frame. The piano tuner may not have the slightest trace of knowledge concerning the crystalline structure of copper, or the tensile strength of the steel, or how many pounds of tension the string is exerting on the frame, but he can do an excellent job of setting middle C at the right pitch and giving all the other strings their right frequency relative to it so that they match the scale intervals, and each one is resonant to the comparable string, on all other pianos. Likewise, an orchestra may contain a score of instruments of different types and, despite their great structural differences, all can be brought into harmony with each other.

In a community structure, if harmonic functioning of all parts is not attained the functional design is probably out of resonance with the universal pattern. Efforts to achieve resonance should be directed first toward testing the functional design and changing it until maximum response is achieved. As these changes are made, structural alterations will take place automatically. If a community should ever achieve full resonance with the uni-

versal pattern, it would manifest a vitality, and a velocity of progress, that would seem miraculous. This applies to individuals, too.

The pattern of a community is existent in intangible factors but it produces material manifestations. The nature of its cities and buildings are an indication. The European cathedrals, architectural blossoms that flowered out of the spiritual values of the Middle Ages, are manifestations of a sense of beauty, and universal power, as a dominant cognition of that period. This cognition produced symphonies in stone, congregations of lofty columns in prayerful processions wearing as crowns arches sweeping heavenward in graceful curves, chanting architectural melodies modulated to the music of the spheres. A cosmic consciousness was carved into their naves and chapels and a reverence responded to the radiance of their roseate windows. Here a human being could be both humble and magnify himself to the majesty of his spiritual aspirations.

In strong contrast is the architectural expression of the later period when political and industrial power were unintentionally divulging their earth-bound conceptions in a bastard Romanesque hybridized with a petty, pretty, piddling rococo and baroque. Architectural courage had vanished from the earth. The expanding cities were flattening themselves over enlarging areas with unending arrays of unimaginative homes, parsimoniously planned, for populations becoming economically more submerged, and with a minimum of community improvements. The pattern of the cities contained all the subtleties of design to be found in a haystack or a swamp morass.

That phase of European development spread to the United States. The Roman pattern of concentrating wealth into the hands of ever fewer individuals operating in the new-rich environment made it possible later for the nuclei of industrial wealth and power to indulge in monumental building operations which symbolized the worship of wealth and power. The community pattern which expressed itself in the canyoned streets

and pincushion skyline of American cities was unique in world history.

Had we been less negligent of the arts and scholarly achievements in the past we might have brought some outstanding new artistic conceptions to that dynamic structure, the skyscraper, but the two developments were out of phase in time. The power and wealth motif under the great-man theory was ready to express itself before we had originated commensurate artistic conceptions to accompany it. The realistic conception of the human community pattern calls for an entirely different form of expression.

A new age is opening with unbounded possibilities for building a better world for human welfare and unlimited resources in energy for achieving any objective we desire. What will be the design motif of this new age? This design will not be created in drafting rooms of architects or engineers but will first shape itself in the hearts and minds of the people of our communities. It will symbolize our utilization of the subtle forces of nature. Our communities will no longer need massive monuments to symbolize private or public power; the monuments created will be in public works but not to symbolize a powerful central government, for we will come closer to the ideal that the best government is that which does the least governing. It will be an era of wide horizons and broad vistas, a time of building in ample spaces. Communities will be built around the principle that individual lives can be planned and lived without economic uncertainty and the full value of lives will find means of expression. Can architects trace that design into working blueprints, and can engineers transform the new community pattern of biologic dynamic vitality into a material expression of structures and facilities that will be in harmony with the all-pervading cosmic pattern and resonant with the reservoir of universal energy that powerizes the paths of progress? That is the challenge of today—to give form and design to human hopes and happiness, to a design for life.

10. INTRODUCING THE HUMAN RACE

THERE is one primary purpose for all human activity—improving the health, comfort, security, happiness, and the cultural and spiritual advancement of the human race. There is no possible way of bringing these benefits to the human race except by bringing them to all of the individuals who comprise the race, and there is no one who can accomplish this purpose except the human beings themselves.

Two approaches appear, on casual inspection, to be available to the problem of working out this purpose: (1) The selfish—let each individual provide for himself; and (2) The altruistic—let each individual concern himself with the welfare of others. On closer examination neither seems practicable.

If carried to its extreme absurdity the selfish approach would require each individual to live an entirely self-sufficient life, have neither need for nor interest in others, and no obligation to anyone else. This would require that the individual be self-creative. It would require that he be not limited by a growth cycle at either end of which he would be more or less helpless. In order to reproduce the race, each individual would need self-reproductive powers. It would require that the environment within his range of activities supply all of his needs. No existing individual possesses these required powers.

The altruistic approach can be presented from an equally extreme viewpoint. No two individuals are identical in their natures or requirements and the number of individuals in the world is very great. The conditions under which they live vary with place and time and likewise their requirements. No individual can become acquainted with the needs of all others

and is totally lacking in ability to meet such needs, even if all of his own needs were supplied by others and he devoted all of his efforts to altruistic purposes.

All such unrealistic generalities lead to fallacious reasoning. It is a fact that the completely isolated individual is an impossible and unrealistic conception and does not exist. Despite the similar extreme viewpoint of the altruistic concept, it is a fact that we do live under a system of altruistic activities and none other is practicable. Within the family-community altruistic system, the individual actually attains the status of primary importance which it would seem, at first glance, would be possible only under the program of dominant selfishness. A combination of the selfish and altruistic systems is essential and unavoidable.

It was indicated in our picture of the cosmos that each individual is the center of the universe, that this universe is co-extensive with the cosmos, and that the cosmos contains as many of these universes as there are individuals. Any individual, attaining a suitable point of perspective, can see the other individual universes merge. An atom in the center of a block of matter would be aware that it is very much like a solar system with a central sun and a family of surrounding electrons, and it would see all surrounding space, which would be the universe filled with similar units. Give this central atom human sensory powers and remove it to a great distance from the mass of atoms it inhabited. It no longer sees a surrounding galaxy of glowing, throbbing atoms, but a bar of steel that seems quite rigid, cold, and lifeless. At closer range it would have seen the steel presenting a very complex structure of crystals of various shapes and compositions separated, or bonded, by layers of carbon and other materials.

There are many realms of existence even for an atom which, alone, presents very definite characteristics; the molecules combine to form crystals presenting new, additional characteristics and masking some of the characteristics manifest in the simpler structures. The process continues as crystals form domains and

domains unite to form masses. These masses form not only bars of steel but also human beings, and all else that exists.

All things are composed of atoms basically similar in nature, capable of most intimate harmonic relations and even interchanging parts of themselves. The atoms appear almost infinitesimally small. But are they? How big is an atom? What are its bounds? Actually an atom is small only because we have declared it small and set an arbitrary limit to its dimensions at the point at which its manifestations go below a limit at which we are able to measure them directly, or conveniently calculate them. An atom is as big as the universe, had we eyes to see it. And the universe is filled with an almost infinitely great number of atoms simultaneously occupying the cosmos.

As with atoms, so with human beings—every human being can be, and is, the center of the cosmos without any interference with the ability of every other individual to occupy a similar position. To each individual the remainder of the universe is the external portion of himself, and even though his feet do not have roots in the ground he is most intimately linked to its entirety and participates in its entire program in all realms from atoms to galaxies.

Each individual is the owner of an entire universe. He is the proprietor of everything he beholds, everything which he can influence, or be influenced by, everything of which he has knowledge in either the conscious or unconscious realm. Every other individual on the earth is included within the universe of each individual. This supplies the fundamental basis for a realistic system of human relationships and for a rational system of social and political ecology.

No spot on earth is foreign territory to any human being; every individual is a part of all other individuals. Every individual has a responsibility for the welfare of every other individual as a part of himself and all of the rights necessary to insure optimum welfare. Each individual carries a responsibility to administer the entire affairs of the human race and will do so through the external portions of himself. He owns all the

world's resources but carries the responsibility to administer them for the welfare of the entire external part of himself, that is, for all men.

Nature has a beautiful technique for balancing extremes. Each individual is supreme ruler of the entire cosmos and the entire human race, but this situation is balanced by the fact that he is influenced and limited by every other atom in the cosmos and is but a tiny fragment in the external portion of a very great number of other individuals to each of whom he owes equal responsibilities. Here is a beautiful state of equilibrium which could be elegantly expressed in a simple mathematical equation.

In dealing with human affairs, however, it will be found that responsibilities do not diminish inversely as the distance between individuals, a concept carried over from physical science (where its validity is not too firmly established as it could vanish under possible and self-consistent systems of spatial relations other than we now use). There are situations in nature in which dimension has no reality and which offer tremendous possibilities for practical utilization but we have not permitted ourselves to become cognizant of them. As we relate ourselves in our conscious thinking and living to the fundamental pattern of the cosmos we will become more aware of their existence and our ability to use them.

The picture which has been presented of the nature of the individual and his relationship to other individuals does not imply a uniformity in the expression of the individual resulting in a moribund mediocrity pervading all mankind. Quite the contrary. Nature has nowhere followed such a plan. There are ninety-two kinds of atoms, each the species-type of an element. They present a wide variety of concentrations of energy and of properties. Each atom of each element serves in nature according to the amount of energy, or mass, with which it is endowed, and the properties associated with that condition. The specific mass, or energy state, permits it to render a particular kind of service. So with human beings.

There is a vast variability among human beings, but the hu-

man race is basically a homogeneous group. All of them, however, can be typed with phylla, genera, species, varieties, types, etc., the subdivisions being continued until there is a separate category for each individual, if desired. We are, every one of us, an expression of the several thousand genes that make up the chromosomes that determine the human form. We assume a norm, represented by a complete set of genes each operating in its appointed cycle to the full amplitude of its possibilities, thus implying optimum environmental conditions. This would bring about the development of a human body and all of its characteristics, which would conform to the theoretical human body norm. This would include the so-called extra-chromosomal factors. It is doubtful if any human being does, or ever has, attained this norm. Every gene and extra-chromosomal factor, through deficiency or excess of operation, brings about structural or functional changes that express themselves in personality, physique, and operational deviations from the norm. Some of these deviations become useful specialized personality characteristics.

Researches by the author indicate that the environmental conditions in the uterus, under the influence of which the foetus starts to develop immediately after conception, which vary with the season in which conception takes place, are a powerful factor in shaping the personality of the individual. The changing uterine conditions appear to exert a selective, controlling effect in determining the degree to which the various genes in our chromosomes will, or will not, express themselves. This indicates that we may have available to us many means for controlling the nature of individuals and the composition of the human race.

These suggestions are put forth merely to indicate that the human individual and the human race can be studied on a purely quantitative and qualitative basis, even when generous allowance is made for undetermined spiritual qualities, as is done in every other field of research, and that human relations can be handled on a purely rational basis. It is essential that this ap-

proach be adopted if we are going to engineer our progress into the new age.

In the field of engineering there is one primary project—engineering our civilization for human welfare. It is quite frequent in all fields to ignore primary essentials and to concentrate on minor, or secondary, objectives. It has, therefore, never been considered desirable or necessary in the past to have the engineer become acquainted with the ultimate objective of all of his activities, the human being, whose welfare he has been striving to enhance.

Before the master blueprints for engineering progress can be drawn, it will be necessary for engineering to become better acquainted with humanity. And before engineering can perform its major service for humanity it will be necessary for humanity to get better acquainted with itself and decide where it is going, to set up the goal toward which it desires to progress, to decide what it wishes to accomplish with the most magnificent phenomenon produced by the Master Engineer of the Cosmos—human life in the individual and human life in the aggregate.

We have in this situation one of those vicious circles—humanity requiring an engineered course of progress if it is to make an orderly advance into the new age, but unable to acquire a chart for a new course unless it engineers its present structure. Likewise the engineers' greatest opportunity for service is to bring the rationality, practicality, and efficiency of engineering techniques into human affairs, to build a bridge between the psychical and the physical, between the living organism of humanity and its environment; but before this can be accomplished it is essential that an artery of communication be established between engineering and humanity. There is a barrier to be penetrated from both sides. This dike of isolation consists of two false doctrines, one that human affairs are not subject to rational treatment, and the other that engineers are a modern version of the high priests of ancient Egypt whose knowledge is entirely esoteric and who serve no one but the king.

There will come a happy day of revelation when the people discover there is nothing mystical, magical, or esoteric about engineers or engineering, and the engineers discover that humanity is not a cacophonic mass of squirming chaos but is a throbbing entity, vibrant in the vital pattern that underlies the cosmos, and that this pattern is comprehensible, potent, and usable.

It is not difficult to understand why the engineer might very well judge the human race irrational. During one five-year period the wealth of the universe is placed at his feet and the highly organized services of the entire community are placed at his disposal to produce marvelous instruments of destruction to be used to shatter beyond recognition an important localized phase of civilization. During the next five-year period he is called upon to go to the scene of destruction and seek to restore it to its original functioning condition and in the meantime to build an iron curtain between the partners in destruction as a means for achieving international understanding.

The engineer in his professional capacity is the most rational of men, but he sees the fabulous facilities inherent in engineering for rendering constructive services applied only too frequently in irrational projects. Situations such as this, in many fields of activity, are changing human beings into split-brained schizophrenics at an alarming rate.

It would be concluded, with ample justification for the decision, that the engineer, too, is irrational, but deeper understanding of the situation would reveal that the irrationality does not have its generative focus within the engineering realm but is projected into that field from external sources.

Early in his training the embryo engineer has impressed on him the dictum, "engineering is amoral." The scientist is given the same story. These budding professionals are taught that the laws of motion operate alike for king and commoner, that the laws of thermodynamics function equally well for Jew and Gentile; that the strength of a beam is independent of whether Republican or Democratic money pays for it; that a floor will

support the weight of a thousand men regardless of whether they are saints or sinners; that the law of conservation of energy is unaffected by the fact that the energy is applied for either social or anti-social purposes. The statements are *so* true!

Then comes the transition to the next step in which it is pointed out in such logical fashion that since the basic fundamentals of engineering are entirely amoral, and since the engineer is only the very human means for implementing these amoral laws, the engineer in his professional capacity must remain amoral; he must never question the morals, ethics, motives, purposes, objectives, of those who engage his training and services to apply the amoral laws of nature to structural or productive activities (excepting, of course, definitely illegal projects). There is added the finishing concept—a democracy can do no wrong.

Therefore, the engineer moves in a sphere of influence in which the executive viewpoint is dominant and in which human beings become statistics and the statistics are subject to the executive, but not the engineering, analysis and interpretation. The engineer becomes estranged from the human race and, like the infant in arms, knows and loves the mother from whom comes the life-giving milk. The situation is very hopeful, however; engineering, like the infant, will grow up, become a free citizen of the cosmos and thereafter take loving care of the mother who nutured him, in the meanwhile taking equally loving care of another mother with whom he has become a life partner, who is presenting him with a growing brood of offspring and through which he will become acquainted again with the human race.

Viewed from the right perspective and with a broad enough scope of vision the whole situation becomes a panorama of growth with the cycles of civilization presenting the same fundamental rhythms as the cycles of life in the individual despite the differences in time in which the cadence is completed.

The boy learns to use tools and enjoys making things. He

achieves mastery of an automobile, is able to take it apart and put it together again so that it runs. He is king of the land, he can go places faster than with the fabled seven-league boots. He builds a boat and puts a motor in it. It plows through the waves. He is king of the seas. He glories in his abilities to accomplish these miracles; he glories in his control of power. He has no time for, nor interest in, those feather-brained females, those gossiping gals, those dancing dames who get in his way and don't know what it's all about.

Not too long afterward, however, this youthful master mechanic makes the astounding discovery that the feather-brained females, gossiping gals, and dancing dames are really quite interesting and not quite so muddle-minded as they formerly seemed to be. They present, he discovers, some intriguing possibilities, some useful attributes and also some prodigious problems with which only the magnificent mentality of the master mechanic is competent to cope—and he proceeds to cope.

The analogy is applicable to the larger scale. Engineering is ripe to fall in love with humanity. As a matter of fact it is about time that engineering settled down and found a purpose in life. And what a thrill engineering is going to experience when it gets acquainted with the humanities. That youthful master mechanic was lifted into a state of almost religious ecstasy when he discovered how much more marvelous a mechanism was a new model baby than the new model car over which he used to rave. No steering wheel ever reached out to grasp his hand, no sealed-beam headlights ever smiled at him, no carburetor ever purred and gurgled at him, and who ever heard of a diminutive Austin growing into a Chrysler Imperial by feeding it gasoline?

The vicious circle described earlier in the chapter which kept engineering and the humanities apart will, through very human processes, evolve and dissolve and the situation will become converted into a merry-go-round as both engineering and the humanities grow up a bit through contact and mutual understanding. The contact should be fertile and prolific.

11. TECHNIQUES OF CONTROL

ENGINEERS are being called upon to develop a social consciousness. Response to the call would be a highly desirable form of professional expansion. Development of a social consciousness by the engineers would be a totally sterile development, however, unless the social scientists simultaneously developed an awareness of the engineers. A cantilever bridge with a single pedestal and with a span reaching halfway across a chasm is not a very effective means of communication. The chasm must be bridged from both sides. There is need for something more than just an engineering consciousness in the social field; there is an urgent need for a rational manner of thinking.

Rational thinking, in its correct and original sense (perhaps it would be well to say in the Greek more than the Latin sense of the word "thinking"), calls for logical thought processes in which recognition is given to the fact that we live in a cosmos, that all phenomena fit into a universal orderly plan, and that every effect has a cause. The Romans gave the word a fuzzier meaning which permitted them to include wise judgment and discretion as an alternative to close adherence to causal relations, and still call the process rational thinking.

In the social or humanitarian field (executive aspect) there is a very definite mode of procedure in which all events that can be construed as favorable are credited to the wise judgment of, and careful planning by, the executive group; and all events that must be evaluated as unfavorable are credited to the stupidities of their opponents, the demoniacal activities of their enemies, or a misfortune visited on them from the hand of the Almighty.

Engineers have no such facilities for crawling out of a situation. If a hot spot should develop along the flow line of a chemical process causing damage and financial loss, the engineer would be called on for an explanation. If he should, with a flow of rhetoric (of which engineers are rarely capable), ascribe the trouble to the stupidities of the Antiphlogiston Party which was in control of the National Chemical Engineering Society during the previous administration, or to an act of God, it is unlikely that he would receive any more contracts for constructing chemical process plants. Such processes of thought would not be tolerated in an engineer. The Board of Directors, however, if shrewd, might recognize in this hypothetical misplaced engineer the making of a valuable executive, make him a vice-president, and place him in charge of government contracts or public relations.

Rational thinking is not a dominant factor in the field of the humanities. The liberal arts courses in our colleges are woefully deficient in providing the instruction on which the foundation for rational thinking can be laid. The essential element for such thinking is training in the natural sciences which demonstrate that we are living in a cosmos in which natural laws are operative, that these laws are universal in their application, and that they are just as effective and as inescapable in the field of the humanities as they are in the field of engineering.

The liberal arts training, even in colleges with a science survey course, can leave a man with only the faintest glimmering of the fundamental idea of a cosmos governed by natural laws operative in, and inescapable in, every realm, which apply to even the slightest item of everyday life, the movement of his finger, the digestion of a meal, his thoughts, his social and economic relationships; and that the entire social, economic, and political structures are affected by these natural laws to exactly the same extent that they govern the shining of the stars and the movements of the planets in their courses. The liberal arts man thinks that with an elastic step and a buoyant spirit, and, because he is

who he is, he can go up a flight of steps without paying full toll to the law of gravitation.

He thinks there is no fundamental difference between the natural laws and the laws enacted in Washington. He thinks that Newton was a great man because he managed to achieve acceptance of his laws of motion without having them enacted by the Parliament. He thinks that if pressure enough is brought to bear on scientists they can be induced to call a meeting of their technical societies and enact more satisfactory laws of thermodynamics. He thinks that scientists are not clever enough to write so-called natural laws that would be effective in the field of the humanities, and, if they were written, their effectiveness would be of such a low order that they could be completely nullified by executive judgments. He thinks any problem can be solved if one belongs to the right political party, knows the right people, has sufficient money or credit, or sufficient cleverness, or by hiring private detectives, or calling out the army. He knows all about the scientific method because that is the basis of the perpetual inventory card-index-system he uses in his business, and is not surprised that scientists make progress by copying and using it. He is convinced that the liberal arts course he took at college made available to him the totality of all knowledge ever possessed by any man since the world began, nothing important will ever be added to it, and is entirely adequate to equip a man mentally to handle the heaviest responsibilities in the social, economic, political, and business worlds, and in the engineering world, too, if he could spare the time to learn how to operate a slide rule, and to close one eye when looking through a surveyor's telescope.

Acceptance of the cosmos would be a severe handicap to this type of person. It would mean a serious curtailment of power, a sharing of his authority with nature, and according to his theory divided responsibility is impossible because it will not work. Suppose a natural law doesn't work! Who will assume responsibility for it, who can be called on to have it amended or repealed?

What procedure is available for having its constitutionality tested before the Supreme Court, or even the State courts? No, natural laws just aren't practical in human affairs and there is no substitute for good executive judgment in solving problems involving human relationships, he insists.

This is the type of liberal arts mentality which dominates the entire political field from the highest federal positions to the local jobs in the village and township. What interest has the engineer in this situation, if any? A very definite interest. In the civil engineering field more than ninety per cent of all contracts are made with municipal, county, state, or federal governments, and during the past half dozen years ninety per cent of the contracts in all fields of engineering have had some government control factor involved in them. This figure may drop temporarily, but the trend toward centralization of power implies a continuation and increase in such situations, regardless of political ideologies involved at any particular time or place.

Not only does this type of mentality dominate the political field, but it likewise dominates the executive sphere in commercial organizations. These are the two purchasers of engineering talent, government and business, and both have the same approach to the fields in which they operate. These are the groups with which engineering, and its population of engineers, must do business.

The typical technical engineer belongs in a diametrically opposed category. He knows that the strength of a given beam, the stability of a particular structural design, or the capacity of a selected tank are not subject to arbitration or negotiation, and no amount of threats or cajoling will alter them. The weight of a designed steel column is not amenable to either bulldozing or propaganda, and the number of kilowatts which can be extracted from a given fall of water, or the productive capacity of a single steelmill will remain fixed despite any of the necessities of a political situation.

At the foundation of the engineering techniques is a set of

inflexible natural laws, but under engineering ingenuity in their application they permit almost unlimited flexibility so that they can be utilized to meet the requirements of almost any situation in which the political official or business executive finds himself.

There is a maximum contrast in the two types of mentalities, yet they manage to do business with each other without exceeding the critical amount of friction. The secret lies in the fact that there are all kinds of executives and all kinds of engineers. They vary in all directions around the median point that represents the typical individual. There is no fixed type of engineer or business executive. All individuals in each group deviate from the purely hypothetical norm of the group.

Many a man with a natural bent for engineering has been forced by circumstances to enter the business world and take over the responsibilities of the chief executive of a corporation. He manifests in his dealings with other executives the characteristics of the liberal arts mentality, for no other response would be understandable in the milieu of the group. But he is a different man in his contacts with the technical men in his own organization. He has a yen for their work and he delights in their rigorous habits of thought and the certainty of the results that can be anticipated under their planning. When thrown in contact with outside engineering organizations he brings a deep understanding of their viewpoints and methods and achieves maximum co-operation and usually a most profitable relationship.

Equally frequent is the converse situation in which a man is torn between two loves, one to become an engineer and the other to become a big businessman. This individual usually achieves both desires. He becomes an engineer. He won't keep his fingers tangled in a drafting machine any longer than necessary. He will talk contracts with greater enthusiasm than design. He is a good mixer and manifests an ability to swing deals. He becomes president of an engineering company. Or he is called

to an executive position in a manufacturing company with heavy engineering problems. He then manifests the executive mentality. He maintains membership in his engineering societies, reads their journals, and attends their conventions, but the engineer in him has thinned to the vanishing point. He finds the meetings of his trade organizations much more interesting and makes more valuable contacts at them.

These two types of individuals are the personalities out of which are constructed the bridge linking the engineering and the executive and political domains. If all engineers could be examined with respect to talents and personality it would be found that they run the complete gamut found in every other field ranging from highly specialized technicians to typical executives. The greatest number would be clustered around the median point in which a good average balance between technical knowledge and executive ability would be found. At increasing distances from this middle point fewer individuals would be found in each group and more highly developed specialized talents.

The Presidents of the United States could be cited as a group exhibiting the executive or liberal arts type of mentality to the highest degree. Yet within this group we find the widest range of distribution. At one extreme we find such types as Franklin Delano Roosevelt and Andrew Jackson exemplifying in very different ways the characteristics of the executive type, and at the other extreme we find those who would adequately qualify as engineering types. George Washington was an engineer; Thomas Jefferson, an architect, builder, and inventor; Abraham Lincoln invented a method for lifting boats over mud flats in the Mississippi, and in a different environment might well have become an engineer; Ulysses S. Grant owed his greatest accomplishments to a flair for military engineering, as at Vicksburg; Herbert Hoover was a mining engineer. All of these Presidents with engineering abilities, however, possessed, also, the human touch in a highly developed stage and it is probable that the

latter contributed much more to such success as they achieved as President than their flair for engineering.

In the present state of society the executive, or political, type of mind is absolutely essential but this is, probably, a temporary rather than a permanent situation. This type of mind has, through age-long manipulation, adjusted all groups to its methods, educated them to accept its justification of control techniques and to believe no other techniques are practical, and to believe that any individuals who propose other techniques must be suppressed as anti-social, as enemies of the state, of humanity, or civilization.

The success of this non-rational (or should it be non-cosmic?) type of mind in dominating the human race is actually one of the most magnificent accomplishments in the field of human engineering, despite the fact that it is motivated in the wrong direction. Those who have manifested it to the significant degree required by leadership number far less than one out of every 100,000 of the population but these leaders, by organizing themselves and controlling resources, have manifested the phenomena of the power of one individual controlling the power of 100,000 individuals. This situation is far from ideal but no other system is practicable until the intellectual level of the population has been raised sufficiently to justify more desirable methods of directing human affairs. This is a task for pedagogical engineers. In the ideally engineered society the entire population will be so well educated and supplied with knowledge that they will know what is best for their own welfare and how to achieve it. Even in this situation, we will be unable to dispense with enlightened leadership.

Educating entire populations to this level is a task of tremendous magnitude, equivalent to, if not greater, than providing a palatial residence for every family in the country. Inability to achieve this educational goal with the resources available in the past has made it necessary to make the best of totally inadequate procedures. Two viewpoints have dominated conflicting camps

of pedagogues. One, the Jeffersonian, called for putting forth extensive efforts to provide the fullest possible education for individuals with exceptional natural qualifications and the necessary minimum for the general population. The other, the Jacksonian, called for providing a uniformly distributed education for the entire population as much above the minimum as possible and let the exceptional individuals take care of themselves. The latter was the basis of the plan of President Truman with the exception that he urged the specialized training of those who would be requested to provide the technical skills needed for a war effort. Education, he held, should not be provided for the benefit of the individual but for national welfare.

The inadequacy of economic resources in the past prevented the adoption of both theories. In our early days we educated our clergymen and depended on them for enlightened leadership. With adequate economic resources the two plans could become mutually complementary. With the wider diffusion of higher orders of knowledge the number of individuals who will be capable of leadership will be greatly increased. Instead of one out of 100,000, it should be increased to one out of 1,000; it would be more desirable to have one out of 100. We would then be approaching the situation in which a true democracy would be possible.

This feat of pedagogic engineering will be achieved only when adequate economic wealth is available and the creation of this adequate economic wealth will be dependent upon the work of the atomic, electrical, mechanical, civil, and all the other productive engineering techniques. It has been created to a useful extent but is being wasted by political powers on other purposes.

The basic wealth of the individual is the years of his life. If the individual has but a short life span, both the individual and his society are poverty-stricken. The average life span is an index of the extent to which it is economically feasible to invest in progress. An average life span of thirty years could absorb or produce little progress. With an average life span of sixty-five years

which we now enjoy it is economically feasible to make extensive investments in progress for the individual and, conversely, the individual has available greater wealth in time and effort to make contributions to progress. This progress will react to provide further extension of the life span.

An important factor in the basic wealth of the individual is the state in which his years are lived—his health. This, in turn, is dependent upon the social and economic milieu of the community. Health is dependent largely upon adequate nutrition and this is dependent upon production of foodstuffs in adequate amounts. This is the responsibility of the agricultural engineers. They in turn are dependent upon the civil engineers for irrigation projects, upon the mechanical engineers for farm machinery, and upon a host of other engineering disciplines.

Nations have life spans in very much the same fashion as individuals. In the slow tempo of the past the life spans of nations were much longer than they are in the modern era. Here, too, the time factor must be modified by the economic and social health of the nation. If the life span were lived on a very low level the total contribution to progress could be much less than the contribution made by a nation with a shorter life span on a much higher progressive level.

Changes take place in nations. The same name might remain but in the course of time the nature of the nation could change so completely that it became an entirely new entity. This change has taken place in the United States. The agricultural United States which existed prior to 1875 is an entirely different country from the mechanized United States of today.

A vast investment in effort and wealth has been made in the new United States under the assumption, of course, that it was going to enjoy an indefinitely long life span of unhindered growth and progress. Similar investments have been made by European countries. The new era started here and abroad about 1875, when railroad extension, steam power, and electrical current made possible a new energy-richer basis of national life.

The German development was an excellent example of the new type of national development.

For some reason, perhaps inherent in the nature of such national developments, it was found necessary, a few years ago, to destroy completely the German development after a life span of about seventy years. The Italian structure was destroyed after a somewhat similar life span. An effort was made from one direction to destroy the Russian development after a life span of about thirty years, and present indications point to an intent to complete the effort from another direction. Fears, real or synthetic, are being expressed that the United States development is in danger of destruction after a life span of about seventy-five years of the new era. A supernational development, the British Empire, until 1940 held a pre-eminent first place in world affairs, and has since dropped to third place. The Japanese development was smashed after a seventy-year life span.

Viewed from the long-time perspective of history, the situation suggests the problem: To what extent is an investment in progress justified in national entities with a probable average life span of seventy-five years? It is not necessary, however, to be too pessimistic about the situation. This catastrophic phase was brought about in a civilization directed by the executive-liberal-arts type of mind, the type that is not conscious of the fact that man and the human race as a whole are part of the cosmos. It seems highly improbable that direction and control based on engineering concepts would have led to the use of catastrophic remedies for problems of international relationships.

Human affairs are characterized by the development of stresses and strains between groups. Some of these are associated with a disproportionate distribution of resources, of manpower or abilities to utilize resources, in a geographical sense. It would not be difficult to resolve such situations into vector factors and to bring needs and facilities into balance on a world-wide basis, and within groups, so that economic and social equilibrium would prevail, if so desired.

Achievement of such a state of equilibrium has not been the goal of the executive directors of national groups at any stage in the world's history. The goal has always been the creation of a state of disequilibrium in favor of a particular national group. This, of course, necessitates a situation contrary to the interests of other national groups.

Individuals, groups, or nations that are on the positive side of a disequilibrium situation are always unwilling to yield what they consider the immediate advantages that accrue to them from such conditions. Under existing conditions, a disequilibrium that has once been established contains within itself the power to increase the state of disequilibrium.

All the laws with which engineers are familiar, the laws of motion, the laws of kinematics, of statics, and of hydrodynamics are as applicable to human groups as they are to aggregations of atoms and molecules. If the effort were made to express social and economic phenomena in terms of these laws, the events which are taking place within groups of all magnitudes and among groups would become more easily understandable, and remedies for undesirable situations would become obvious.

This is not, however, a statement that all phenomena involving social, economic, or national groups can be stated in terms of purely material concepts. The contrary statement would be more truthful. Nevertheless the technique of controlling large numbers of individuals in national groups, whether for constructive or destructive purposes, has its analogues in engineering practices.

If a national group is engaged in a certain line of activities and it is desired to change the direction in which these activities are aimed, or if the group holds a particular attitude and it is desired to change that attitude to another angle, the change involves work, and work involves expenditure of energy.

Moving a large body quickly involves the expenditure of energy at a rapid rate with a consequent heavy drain on power sources. If the source of power is limited and likewise the rate

at which it can be expended and the body to be moved cannot be reduced in mass, then the body must be started in motion at a very slow rate and accelerated at a very slow rate requiring a relatively long time to bring about the desired change in position or direction. If the body can be divided into small units the power available can be applied to one unit at a time and a quicker start obtained in this way.

This latter principle is used in applying the power of a locomotive to getting a long, heavy train in motion. If the forward thrust were applied at the same instant to all of the cars, the locomotive might be unable to move the train from a standstill, as the inertia and friction encountered along the entire length of the train might be in excess of the tractive effort applied. If, however, the train could be divided into one hundred units of one car each the locomotive would be able to accelerate each successive one-car unit until a relatively high speed is reached. This principle is incorporated into all trains. Adjoining cars are linked together by a coupling device in which the coupling rod has freedom to slide forward or backward several inches before it makes an unyielding contact with the next car.

If the train is made up so that this full sliding distance is made available between each car, then the first car can be accelerated through a distance of six inches before it starts pulling the second car and through twelve inches before the load of the third car is taken on and so on down the length of the train. In this way the locomotive will have advanced fifty feet before the last car of a long train has started moving.

A large national group can be directed by a small group with adequate power, by dividing it into small groups and moving them one at a time. If the power is applied discreetly to carefully selected groups at first and the rate of acceleration is held below a certain critical level the large national group can be moved as desired without its becoming aware of the change until the acceleration has become so great that no one group is able to apply any force that would be effective in stopping or halting the mass

movement. This technique could be used by a single individual in a strategic position for moving a nation to either constructive or destructive purposes. It is doubtful if it has ever been used for constructive purposes.

When a constructive purpose is the goal, the sliding-drawbar-small-unit principle is almost never used. The limited amount of power is applied at a low rate of expenditure in an effort to move the entire national mass as a unit. The lack of noticeable acceleration causes a hurried decision to be reached so that it is impossible to achieve the proposed movement and the nation is not ready for this constructive effort. The objection is never raised that the power behind the effort was insufficient or the rate at which it was applied was inadequate. An engineering analysis of the situation would take all of these points into consideration.

The executive directing mind is well aware of the fact that changes in attitude toward any direction can be achieved by starting with a slow rate of acceleration and keeping the pressure steadily applied, and that the entire nation can eventually be set in motion with tremendous kinetic energy toward any desired goal.

How this is accomplished is indicated by an experiment made in Bell Telephone Laboratories some years ago in connection with the study of sound phenomena. A rifle was discharged and a sound-strip record made on a movie film of the sound of the discharge. When this sound-strip record was run through the reproducer the loud speaker gave forth a tremendous "bang." The record was run through the reproducer backward and the only sound that come out of the reproducer was a mild "swish." It was identically the same sound record that produced both sounds; nothing was changed but the direction in which the sound-strip passed through the reproducer.

An important psychological phenomenon is involved in this strange change and an understanding of it will make clear to a national group how it happened to go haywire on some current craze, or how, while it was intent on the arts of peace, it suddenly

awakened to a realization that it has embarked on a wild war urge.

Sound is produced by waves moving through the air. The length of the wave fixes the pitch of the sound and the energy in the wave determines the amplitude or intensity of the sound wave. In the case of the sound of the rifle shot, the explosion created a compressional wave of extremely high intensity which was followed by a series of waves, or reverberations, each one of which was of lower amplitude or intensity than the preceding one. In other words, the sound died down. An examination of the light and dark bands on the sound-strip record showed this situation quite clearly.

The hearing mechanisms responded to the first tremendous wave of sound which was so intense that the ear was rendered insensitive to, and could not hear, the lesser sounds that followed. The total hearing response was, therefore, just the first bang, the lesser successive sounds being lost on the paralyzed state of the ear nerves.

When the sound record was run backwards an interesting situation developed. The first sounds reproduced were the low energy waves that were recorded just as the sound was dying out. The next produced were the slightly more intense waves and the last to be produced was what was originally the first extremely intense wave of the explosion—the bang.

When the ear starts hearing from an undisturbed condition it is able to hear sounds of very small energy. If it has heard a sound of given intensity that sets a new level of response then the next sound will be heard with reference to this new level and not with respect to the much earlier state of absolute quiet. If a series of sounds are transmitted to the ear in rapid succession, each sound having an intensity double that of the preceding sound, the tenth wave would have an intensity 1,024 times greater than the first. The ear, however, would be totally unaware of this final maximum intensity. The entire series of sounds would be heard by the ear as a sound of an even level of

intensity. Each sound heard sets a new zero level equal to its own intensity for the succeeding sound so the great bulk of the total volume of sound is lost and the great intensity of the final bang is submerged and inaudible in the unheard portion—like an iceberg with its greater volume hidden beneath the surface of the ocean.

What we hear, therefore, depends not so much on the actual intensity of the sound but the intensity relative to the sound previously heard. All the senses have a parallel type of response and our mental picture of the external world is constructed out of the impressions our sensory organs transmit to the mind. What we learn about the external world of human affairs is conditioned by our previous educational experiences.

The social implications of this situation are of fundamental importance. It provides the basis upon which any program can be "sold" to a nation. A war project, for example, which would be rejected as fantastic, wild and insane, not to mention anti-social and totally uneconomic, if presented cold to a people, can be put across in its totality if presented discreetly—just a little bit at a time. The project must be given the proper emotional settings in the correct order—sympathy, love, home, mother, children, fear, hate, horror, self-defense. A little experimenting will show how much stimulus a nation will absorb without causing a critical unfavorable reaction. A start is made with axiomatic truths but as the emotional potential rises the truth requirements diminish to the vanishing point. Each time this stimulus is absorbed, it sets a new zero level on which a new stimulus can be added, making the new absorbable amount double that of the original unit. After a series of such procedures it is possible to embark on talk about providing men and money to defend the nation's neutrality, more men and more money to fight a defensive war, more men and more money to make a strong offensive as the best defensive measure, more men and more money to carry the offensive to the enemy's country, more men and more money utterly to destroy and wipe from the face

of the earth the enemy who is trying to destroy a peace-loving nation.

This technique has been used in extenso in all the leading countries. None of the peoples in this or any of the other leading countries was free from this type of executive direction. And all have wondered how the final critical situation came about.

Situations of this type have their prototype in the life of the individual, the immediate parallel being the pathological state known as the manic-depressive psychosis.

Two successive phases are characteristic of the manic-depressive psychosis. As the manic phase comes on, the patient experiences an unusual enthusiasm, a sense of elation develops. He can work without fatigue, hard tasks seem easy to him. He loses his sense of perspective. He becomes dominating. Anything he undertakes becomes a matter of extreme importance. He becomes aggressive in furthering his projects and cannot tolerate a lack of enthusiasm in others. Opposition to his ideas bring a violent reaction and if thwarted he will not hesitate to commit assault or murder.

The onset of the depressive phase is characterized by a feeling of fatigue becoming apparent in connection with his efforts. The sense of elation vanishes and fatigue dims his enthusiasm. His sense of values becomes distorted. He feels he lacks sufficient energy to solve his problems which retain the tremendously exaggerated dimensions to which he magnified them in his earlier phase. He is unable to concentrate. His memory fails him. He is utterly unable to cope with the problem from which he cannot dissociate himself and with the depression that has come over him. The victim frequently commits suicide as a means of escape from his troubles.

Post-war situations of nations correspond very nicely with the depressive phase.

It becomes apparent that the task of bringing a social consciousness to engineering and an engineering consciousness to the social structure opens a vista that is as wide as civilization it-

self. Just hitting a few of the high spots, as has been done in this chapter, may indicate both the complexity and the simplicity of the problem that would be encountered in extending the rational engineering concept to the field of human relations. Every physical accomplishment of the engineer has projected powerful forces into the social and economic milieu, but the engineer has never followed through to give thought to the effects produced and his possible responsibilities for control of them. This is the basis of the call for a social consciousness in the engineer. If the engineer responds and shoulders this responsibility we may find that human situations are neither so chaotic, complex, nor fuzzy as they seem to be when viewed through non-engineering eyes.

12. ORIGIN OF ENGINEERING TECHNIQUES

ALL THE arts used in engineering techniques have their origin in nature. Nature was the first scientist, inventor, designer, and engineer. Every modern concept can be traced to a natural prototype. There still remains in nature a vast untapped reservoir of ideas which we shall adapt later when we begin to understand the lessons that nature is trying to teach us.

Modern engineering has gone far in producing its structural and operational wonders, but nature has gone much farther. Man has accomplished much in making mineral and metal devices but he is a long way from learning how to use the secrets which nature knows and has used in making her much more magnificent mechanisms—the meat machines, as we may, for the moment, refer to her living organisms.

The man who first used the lever principle may have thought it a great original accomplishment. It has been of inestimable value to man, but the first man to use it was not the originator of the idea. Nature had been using it in her living structures for many a century. The arm that pulled the first lever was itself a lever. It was not only a simple lever, it was a compound lever and in addition it was a motorized lever for it contained a muscular power supply mechanism.

Was the bellows a useful bag to blow a hotter fire, and was its invention a brilliant feat? Unquestionably. But its inventor who told his fellowmen of his accomplishment was using nature's bellows, the lungs in his chest, to blow the air of his conversation to his listener's ears.

Of greater utility was the invention of the fluid pump. It came in installments, the single rope-raised bucket, the chain of buckets, the bucket on a lever, the turning screw, the pneumatic lift and finally the force piston and the centrifugal pump. It was not until the force piston type of pump came after many centuries of effort that man made any significant progress toward copying the force pump operating day and night in his chest—his heart, and the peristaltic pump that progresses food along the intestinal tract. Nature uses an even simpler pump for raising sap to relatively great heights in trees and we have not as yet fully fathomed her secret.

The prototype for piping systems for distributing water was to be found in the living body, and it was fully supplied with valves. Storage tanks? The stomach and bladder are early models of storage tanks.

Was it a clever artificer who learned how to control fire, to enclose it within materials that would not be consumed by the flames, and thus gave us the stove and furnace? A very clever idea and an extremely useful one. The energy that nature stored in the wood of trees was thus made available for man's purposes. Bricks and stones (and later metals helped) contained the burning material and were not themselves damaged. An excellent accomplishment, but nature is still a few steps ahead of us.

In the human body nature burns fuels, produced in the same way as wood, obtaining just as many calories of energy, and carries on the process with so much ingenuity that it is operated within living structures extremely sensitive to damage without the slightest injury to them and does not exceed the comfort temperature level of approximately 100° Fahrenheit. She has learned how to burn fuels efficiently in a series of steps whose chemistry is still a problem we have not completely unraveled.

The telegraph and telephone are modern accomplishments, products of the past century. Nature has been sending intelligible signals over long conductors for many a millennium. Her wires are the nerves. The signals she sends over the nerves

are largely electrical. She even developed the technique of insulating these wires. The myelin sheath of fatty substance with which she surrounds the nerve tissues are non-conductors of the signals the nerves carry. The voice is produced by nerve-modulated vibratory chords, the original "speaker."

Machine packaging has made the modern food retailing system possible. The idea is hardly original, as nature has furnished many hundreds of models from which to copy, the orange, the nut, and the egg being typical examples whose excellence we have not quite succeeded in equaling.

Is weaving of fabrics a purely man-made accomplishment? One has only to remove the green outer layer from the fronds of the palm tree to discover underneath the fine network of criss-cross fibers which could be presented as lesson number one in fabric making, and this was written by nature in her very early days.

Did man succeed in doing something original when he developed the electro-magnetic principle, the basis of electrical machinery? The earth is a giant electromagnet, not a permanent one of the horseshoe type, but one whose magnetism is maintained by a vast river of electrified particles flowing around the earth like a current in space such as the stream of electrons used in the atom-smashing betatron built in recent years in the General Electric Laboratories, and this, like the cyclotron thus becomes a copy of nature's mechanisms.

Is atom-smashing new? It would have been if nature had not been performing the feat with cosmic rays in our atmosphere since time immemorial.

But vacuum tube radionics must be new! Nature was the pioneer even in this field. The neon tube lights which fill our cities at night with a ruddy radiance seem like a very modern development. It is, however, just a small packaged unit of the aurora borealis, or northern lights, produced by nature when she shoots electrons from the sun through the low pressure regions of our upper atmosphere.

Radio new? Just a highly specialized form of nature's telepathy and clairvoyance.

The internal combustion engine, it may be urged, is something for which nature has produced no counterpart. This is far from true. The human body, and that of every other living organism, is an internal combustion engine which transforms food fuel into power. And man has not yet achieved an engine which can provide its own fuel and maintenance.

Nature has performed her finest engineering feats in her living organisms. We have only in recent years achieved slick streamlining in our airplanes, but nature knew all about fluid resistance a long, long time ago, and provided her fishes and birds with minimum resistance contours and surfaces. She had learned that primary principle of engineering practice—design for economy of effort.

Nature pioneered in the building of articulated structures. The invention of bones was a magnificent achievement. Our skyscrapers are structures with steel bones and stone skins. The human being, as a biped with erect posture, may be likened to the skyscraper in the animal world. The human being incorporates the solution of innumerable fundamental engineering problems. The torso and head are built on the pelvis as a foundation but the pelvis is a moving structure which wobbles, which rolls and pitches like a ship, and is mounted on top of two ambulating structures, the legs, whose design lacks elements of static stability. On the pelvis as a foundation is built an articulated column which carries much of the weight of the torso and head and possesses a high degree of flexibility. The spinal column is placed far off the axis of the structure.

Anthropologists have called man a mechanical misfit and engineers would have to look long through their textbooks to find any principles of design or construction which would justify their adopting the basic design ideas incorporated in the human body. Nevertheless this is nature's finest engineering achievement. Those who have to live in the structure can testify that as a

mechanism it achieves a high order of merit in fulfilling all of the reasonable demands of its occupants, in the efficiency of its operations, in original cost, maintenance charges, and rate of obsolescence. Artists find its best examples meet their maximum beauty standards.

Biologists, physiologists, and anatomists who best understand its structure and operations marvel at the interlocking intricacies, confusing complexities, and basic simplicities that the body uses in attaining its ends. They are utterly amazed by the way in which the living organism utilizes chemical and physical processes which are thus far beyond the power of the conscious mind to understand, and are completely baffled concerning the source of this knowledge. There are two schools of thought in the matter, the physicists and the vitalists, but they are basically in harmony because they both admit there is a tremendously vast area of knowledge concerning living organisms which we have not explored.

There is much in common in a structural and operational sense between human beings and quadrupeds and all other types of living things. If man can be likened to a skyscraper the quadruped can be likened to a cantilever bridge. An illuminating discussion of the engineering phases of the structural aspects of animals is to be found in *Growth and Form,* by D'arcy Wentworth Thompson.* The details are not pertinent to the present discussion, but his findings that there is a systemic control underlying all deviations from norms and that the most fantastic structures can be shown to be intimately related to normal forms are very important. The book should be required reading for all who would see engineering in its broadest aspects.

The task of the present chapter is to indicate that nature has been in the engineering business for millions of years, has done a lot of experimenting, and has achieved solutions of problems which have met the test of practicability under a wide range of conditions. It is amazing to learn of the number of seemingly

* The Macmillan Co., New York.

modern inventions in which man was anticipated by nature; and her treasure chest is far from being depleted for the individual who sincerely tries to understand her message and does not try to force the universe to operate according to his preconceived ideas.

The modern science of optics has been developed during the past three centuries, but nature has provided man and other organisms with a marvelously designed optical instrument—his eye. This supplied man with a model for making spectacles, microscopes, telescopes, and cameras at any time he was ready but it took him a very long time to get ready.

In the eye we find an amplifying principle in operation very much akin to that used in our electronic vacuum tube. Each quantum of light that passes through the lens of the eye and falls on a particular one of the nerve endings, a vast multitude of which carpet the retina, carries but a very small amount of energy, not adequate for the seeing process. The nerve ending stores the energy received by building up chemical changes, and when the energy stored reaches a critical amount—about a total of one thousand light quanta—it discharges the entire amount along the optic nerve which carries it to the proper area of the brain where the sense of vision is produced by the continuous discharge of a vast number of the nerve strands.

The ear is a very sensitive instrument for detecting the energy delivered to it by sound waves. The moving molecules in a sound wave carry a great deal of energy compared to that which is carried by a quantum of light. Some sounds carry an undesirably large quantity of energy so far as the ear's requirements are concerned. Its purpose is not to measure the energy in a sound wave but to detect its existence so that it can be identified. Its problem is just the reverse of that of the eye, so nature had to develop an oppositely acting principle for that organ—a response-diminishing device. She did it in a very clever way by incorporating a logarithmic response mechanism, which operates on this pattern: If a sound of given intensity produces a one-unit response, a

sound of ten times that intensity produced a two-unit response and one of one hundred times the original intensity a three-unit response. Archimedes discovered logarithms two thousand years ago, but it would seem as if nature discovered them a long time earlier.

The whole realm of biology is an untapped reservoir of ideas capable of application to engineering problems. A vast realm of knowledge in this field exists, not in predigested form in which it could be lifted over into engineering handbooks, but the information is available for those who seek it. Why should an engineer inform himself of matters biologic? Perhaps the answer may become more obvious in succeeding chapters.

13. THE CITY IS A LIVING THING

THE PHYSICAL equipment of a city is the body of a civic community that occupies it, just as the human body is the habitation of the spiritual entity that occupies it. The human component of a city is a living, organized entity manifesting in its organized life characteristics that are beyond those found in its individual members. The buildings and other civic improvements which these organized individuals have produced to maintain their life as a community are an inherent part of themselves to the same extent that the food which an individual eats later appears as a part of the vital, living organism.

Life is a phenomenon with definite engineering aspects. It can be described, very inadequately and incompletely of course, under the laws of thermodynamics, particularly the first law which states a definite reciprocal relationship between the amount of heat or energy consumed and the amount of work performed. The second law is variously stated and interpreted. In the field of mechanics, it is of very definite utility, but in some departments of the field of theoretical physics, and in the field of biology and the humanities, its validity is in question. These objections may be the result of inadequate knowledge of the phenomena studied rather than the inapplicability of the law.

The second law of thermodynamics, as taught to physicists, states, "It is impossible by any continuous self-sustaining process for heat to be transferred from a colder to a hotter body." When taught for engineering purposes it is stated that no machine can completely transform heat into work and that some heat must be rejected unused.

Many biologists and many physicists insist that the phenome-

non of life is a contradiction of the second law of thermodynamics, that life is a building up and progressive phenomenon in a universe in which all other phenomena are working downward on the energy gradient. In the field of economics we find vast numbers of individuals with a low wealth-potential making contributions to build up high wealth-potentials in the hands of fewer individuals already possessing high wealth-potentials. This process would appear to be working contrary to the economic analogue of the second law of thermodynamics. A more complete statement of the situation, however, would show that the operation is carried on within a system of environment in which abnormal potential states are maintained.

Until better support is brought to the objections to the second law of thermodynamics, engineers will continue to consider the law valid and interpret social and economic as well as physical phenomena in terms of it. Except in rare situations the law of conservation of mass is considered just as valid by the engineer as it was before the transformation of mass into energy was demonstrated. Likewise it is only in extremely rare instances that any engineering calculations based on Newtonian mechanics require a relativity correction.

Engineering in its broader aspects, however, will not be free from the effects of these scientific developments. The transformation of matter into energy, which will be considered later, will, for example, open a wide new field of engineering that will change the whole aspect of our present civilization.

The city is almost entirely the product of the engineer. It is a living, growing thing whose expansion is forced by the increase in number of the individuals who occupy it just as the human body increases in size by the increase in the number of cells it produces. Cities are of all shapes and dimensions just as there is a vast variety of forms and sizes of living organisms, and cities have personalities. A city exhibits every phase of the life processes found in an individual; a city is a living individual.

The simplest form of living thing is the single-cell animal.

It is like a ball, and is just a blob of highly organized protoplasm contained within a skin. It takes in its nourishment through the skin and excretes its waste matter in the same way. It is analogous to the hamlet in a remote region that supports itself almost entirely out of its own environment on a low cultural level.

The more complex forms of living things are made up of vast numbers of cells organized into groups, each of which takes over a specialized activity, but all co-operating under a single plan. The form changes in much the same way that a circle changes into an elongated ellipse with a major axis through the center and lateral extensions (corresponding to arms and legs) developing out of each of the two foci. Down through the center along the major axis a canal is developed in one end of which the food is taken, through the walls of which nourishment is extracted, and out the other end of which the unused remains are ejected. The ejecta, however, are not necessarily waste material but may contain products of great value elsewhere in the ecology of nature.

The village with a main street and a few lateral side streets is the analogue of this simple type of structure. Some of the very simple organisms, yeasts and bacteria, eject, as products of their metabolism, substances such as alcohols, acids, and vitamins that are essential to the life processes of more complex organisms. In the same way the small village in an agricultural or mineral environment yields products essential to the welfare of the larger communities.

As the organism becomes more complex and engages in greater activity requiring more energy it becomes necessary for it to consume more food fuel. To handle a more extensive food supply it is necessary to have a longer digestive tract so the central tube is elongated to provide more active surface. To contain the longer tract the tube is folded or coiled within a cavity. Irregularities in the food supply make it necessary to provide temporary storage facilities, so near the intake end of the tract the tube is enlarged into a cavity. Thus are the stomach and intestines developed.

These developments require other concurrent developments. Since the organism will have periods of quiet in which little energy will be used, alternating with periods of great activity in which there will be peak demands for energy, and the energy will be expended at a faster rate than the digestive tract can produce it, there will be need for a storage vault for the nutrient material produced in the quiet periods. Thus the necessity for the liver, where high energy chemical compounds can be stored in cells that will not use it for their own advantage but keep it in reserve for the rest of the body.

If the organism is going to consume more fuel it will require more oxygen. In its lowest forms it was able to take in through the outer skin all the oxygen required. A greater amount of active area would have to be provided. This could be provided by increasing the size of the body but this in turn would require the expenditure of more energy for moving the structure, more locomotion equipment, and reduced efficiency. In order to obtain the larger area, the folded surface plan was utilized in the form of a large number of tubes providing a large surface adsorption area in a relatively small volume of space—like a heat exchanger or a radiator. Thus came the lungs.

Distortion of the surface membrane, or of the surface cells, by contraction or expansion of their surface or axis provided locomotion in the simpler state of the organism in its water environment. With an increase in available energy, as the organism adopted more efficient and more productive methods, a greater investment in locomotion equipment becomes possible and at the same time necessary, in order to obtain the additional food required.

When the organism becomes polarized, with a head and a tail end, with the head end taking over the task of gathering food, it became desirable so to propel the organism that the head end could be directed at the food supplies; thus the locomotion arrangements were devised with this purpose in view. An increase in the number of contracting cells at suitable points led

to concentration of tissues that would eventually develop into muscles.

The organism was becoming heavy and, for existence outside a supporting water environment, stiffening elements were required to maintain the structural integrity of the group of organs so rigid units were developed. They were constructed out of mineral matter extracted from the food substances, cement columns, which became the bones. These made possible the utilization of the lever principle, the cantilever structural principle and greater complexity of structure with consequent greater diversity of activities.

The demand for high work outputs by specialized tissues during periods of peak activities necessitated quick delivery of energy substances from the liver storage reservoir. This made necessary an extensive piping system carrying energy fluid to all parts of the organism and a similar system for carrying away the waste products. The arteries, veins, and heart were developed to pump these fluids.

Since the organism originally embarked on a program of development involving specialized activities of each of its parts and the co-operation between the specialized structures for the general or overall purpose of the organization, it was necessary to have a control mechanism to regulate the time and extent of the activity of each part. Thus came the brain, the nerve system, and the associated system of hormone glands.

This organization plan, however, would not have been possible if it were not for a very clever provision by nature in which every cell in the highly complex organism retained the basic individuality which it possessed when it existed as a simple one-cell organism. In every cell of the most complex organism, even those doing most highly specialized work, there exists in its genes and chromosomes and in the molecular structure of its nucleus the complete blueprint of the entire activities of the total organism—one out of many, many in one.

The modern metropolis, with all its complexities, functions

in its growth and activities very much like a biological organism. Engineers build cities; they are really building living organisms. In order properly to design cities as living entities it is essential that the designer have not only an extensive knowledge of biological phenomena but also a deep reverence for the subtleties of human life and the effects of environment on the expression and unfoldment of the unplumbed resources of the personalities of individuals.

The city cannot go abroad foraging for its food; it has a fixed habitat. It has no legs, no powers of locomotion. In nature, function determines form. Instead of moving to its food the city has its food moved to it, likewise other materials it requires. Instead of providing locomotion for itself, it provides locomotion for the required materials, and transportation channels—roads, canals, railroads, ship lines. These are the city's legs, its form of locomotion.

Each city may be visualized as something like an octopus, with a large number of legs reaching a certain limited distance into the circular area around it. Legs are living things, too, regardless of the form they assume. As we look over the existing situation we find that these transportation legs of the cities have formed themselves into a co-operating organism. The railroads emanating out of all cities, for example, have merged themselves into a single functional unit of transportation. The same organization activity has taken place with respect to roads. Both transportation channels have become interlinked in their functioning and the other forms fit themselves into the organized picture.

If we take the railroads as the characteristic element of this transportation system we find the United States covered by the network of this locomotion organism with concentrations of the lines at various points. At these points we find the cities located. These lines carry nutrients, energy, and materials from peripheral to central areas with respect to particular points. Here we have the picture of a large number of cities, of all sizes, intimately linked to each other and forming a super-organism

composed of cities, just as each city is a super-organism composed of individuals.

This super-organism of cities, which will be discussed later, is a living thing in which each city corresponds to a specialized group of tissues performing a special type of service with respect to the environment in which it is located. Under the co-operative system inherent in organisms each receives from other cities what it needs in order to carry on its activities and it supplies, in exchange, the products which result from its activities.

An organism of such dimensions likewise has a fixed habitat. Its relation to its environment is very much like that of a tree to the ground; it obtains its nutrition from the region in which it is located. If there are any deficiencies of nutritive elements in the environment the organism will be limited in the degree and kind of its activities. It can adjust itself to this environment, however, and live an entirely adequate existence. If these deficiences could be supplied it could function in a maximum state of efficiency and with maximum activity and growth.

If a similar super-organism in some other habitat possesses an excess of the materials in which it is deficient, it then becomes desirable to develop a transportation channel linking the two areas. With a network of such channels linking all super-organisms they become co-ordinated on a still higher plane and form a hyper-organism.

In this manner the principle of organism has spread over the earth with the necessity for co-operative effort permeating the full extent of the world-wide organism.

Just as the engineer has built the city and the super-organization of cities, so he will have the task of building the hyper-world-wide-structures.

With the world-wide picture presented as that of an organism, the development of the world's resources becomes a matter of systematic development with the ultimate welfare of the race as a whole as the goal.

The growth and development of the various sized units have

been dependent upon the amount of energy available not only in the form of food but also in the form of physical energy. In the future the amount of energy available will be vastly increased and the activities in every unit will be greatly expanded. Changes will take place not only in the forms but also in the functions of the units.

It is quite impossible to determine, with any degree of certainty, what the specific nature of the change will be which will start taking place in the near future. Even though it became evident what the natural course of events would be, there is no certainty that such a course will not be extensively modified for purposes of expedience.

There appears, however, to be a strong probability that the city unit will vastly expand in area and greatly diminish in density of population and that farm areas will likewise diminish in extent through greatly increased yields per acre. The great concentrations of industry are likely to be dispersed into widespread smaller units. Purely cultural centers may increase in numbers and dimensions replacing the residential and manufacturing cities. Transportation requirements are likely to increase greatly. Air transportation is likely to remain a relatively small magnitude auxiliary to surface transportation. High speed subsurface transportation may become the major form of this utility.

Regardless of what form the changes take, there will be definite basic requirements which will be dictated by the nature of any community as an organism and this will give the cue for the engineering requirements.

PART FOUR

CREATING THE CITIES ANEW

14. CURING URBAN ULCERS

MOST CITIES are municipal monstrosities, community catastrophes, civic cancers, or urban ulcers, exhibiting as social symbols a vast deficiency when compared with the highest ideals of their inhabitants. This does not deny them magnificence in some of their aspects, grandeur in some of their vistas, awe-inspiring attributes in some of their structural achievements, vast utility in their operations, and monumental significance as indicators of man's ambition and ability. Nevertheless our cities stand as a symbol of an age that is closing and in the coming days we will "mold them nearer to the heart's desire."

Cities must be rebuilt—and not where they are. That is an engineering job. What a task! What a challenge! Where will they be built, and how? Geography becomes a factor; also history, economics, and biology. The present unrest marks the close of an era and presents us with a very pressing and pertinent question: Is it worth while to undertake the task if the new structures are to be destroyed in war-making activities? The answer is, we are going to come out of our power debauch and return to a commonsense basis of thinking in a short time. We can be optimistic about the future. Life will continue. Nearly all evils carry the elements of their own destruction, thus furnishing the answer to problems that seem otherwise to be without solution. We can proceed as if the existing situation were merely a minor irritation. Civilization is pregnant with a new age. The international spasms of the past quarter of a century are the labor pains. The birth of the new era is about to take place. It will come with a flash of illumination and will be born in the heart and mind of every man. With it will come emancipation from

the past simultaneously with a revelation of our real legacy from the past and the freedom of the future.

With the new day will come a new sense of ethical values, likely to be the most dominant factor of the new age in the shaping of the material structure of the new civilization. A simple development of this sort will cut many a Gordian knot that is impeding fundamental human progress.

Our cities have been located under expediences of early days, the limitations of an early poverty-economy, and the stimulus of commercial situations which no longer exist.

New sites for cities can be chosen. The geography of resources may be the dominant factor. Pittsburgh is typical of the city based on local resources. Chicago is a crossroads city. Boston and San Francisco are waterfront trading posts. New York was, too, but tried to become a complete nation. Washington is a national town hall—a glorified "county seat."

Foreign trade normally accounts for about five per cent of the total business done in the United States but the business done in the coastal belt from Portland, Maine, around the Atlantic, Gulf, and Pacific shores to Portland, Oregon, probably accounts for between half and three quarters of the total business done in the country. Business institutions and the population dependent on them are no longer anchored to these cities, other than those directly concerned with foreign trade, but nevertheless they remain in these waterfront regions. The present density of population in the coastal areas is a relic of the days when foreign trade was the mainstay of the nation and transportation facilities were totally inadequate.

The nation would be healthier with organic cities—areas in which activities concerned related industries and particularly when these are related to their environment. The natural advantages of such a situation have dictated the location of many of our cities as, for example, Pittsburgh, at the focus of the iron and coal supply areas for iron smelting. There is no geographical necessity, however, for the steel fabrication industries

clustering around that area. The topography of the valley is very unsuited for a city the size and smokiness of Pittsburgh.

San Francisco, as a city, is a monstrosity. Its region of hill-studded landscape is suitable for a park and nothing more. It is totally unworthy of development as a densely populated community. It is climatically unfortunate, for its location is in an area of perpetual fog production, a penalty for the conditions which provided the region with an excellent harbor.

All of our cities are entirely too large. We have failed to provide them with growth-limiting factors. Nature plans more wisely. In the egg the growth process of transforming the albumen into a chick proceeds at a tremendous rate during the period in which the yolk is being used to provide the material for the internal structures. The white of the egg supplies the material for growing the skin, muscles, and associated structures. The yolk contains a very small amount of an extremely powerful growth stimulant, biotin, which speeds the internal development. The white contains a small amount of a substance, avidin, which has the property of neutralizing the activity of the biotin, and preventing growth. When the development of the chick reaches the point at which the external covering is placed on the organism it releases into the operations the avidan previously held immobile in the white and this slows down growth of the internal organs. After the chicken is hatched, growth goes on a new schedule under other controls, located in the glands of internal secretion, and stops when the bird reaches particular dimensions. That is why a hen does not grow to the size of an ostrich.

Human beings are provided with a growth-limiting organ. It is the thymus, a gland behind the breast bone in the upper part of the chest. It is large in early life and disappears at puberty. Its size is directly proportional to the change in rate of the growth curve of the body. Its function appears to be to check the pituitary gland which if left unguarded would increase the size of

the body until the individual became a giant. Giants don't live long.

All of our major cities are pituitary giants, or more correctly they have developed from pituitary giants into civic tumors in which growth continues with almost total loss of the organic pattern of architecture. Cities lack power of locomotion. They must remain fixed in location. When a living organism reaches its maximum growth and starts reproducing, its offspring do not remain within the body of the parent but go off and live in a separate location. Two individuals that remain united to each other, of which Siamese twins are typical, have limited survival value as individuals and are of practically no social or economic value as units for building communities. Our cities are heterogeneous masses of pathological specimens of socially deformed communities.

Since our cities lack power of locomotion and cannot, in whole or in part, migrate to new locations, it is necessary that those developing portions capable to growing into separate organic communities be transplanted to a new location where ample facilities are provided for their growth to maturity and continued existence in the matured state.

The happiness of a normal man is not increased if he is transformed into a giant. Our record-breaking pituitary giant weighs more than 425 pounds. Three normal men, weighing 150 pounds each, would, through their activities, be nine times more valuable to a community than one giant. So with cities. The cost of size is too tremendous a burden.

It is necessary to recognize the reproduction process within a city as distinct from the normal growth process and to provide civic obstetricians who will direct the parturition operation and see that the newly developing community is properly posited in the municipal maternity ward.

Such procedure will, of course, require a new approach to the legal foundation of city, state, and federal governments, a

change whose necessity has long been apparent but which cannot be achieved until the law, like engineering, develops a social consciousness to replace its present political loyalty. The law, too, will be re-established on a biological basis in harmony with the new age. These changes, however, require no revolutions. The old, fertilized by new revelations, evolves into the new by entirely natural processes.

Our cities have been developed as if each were intended to be the self-sufficient center of a separate nation surrounding it. Such a development could be anticipated under the doctrine that the city is the child of the state, that the interest of the state is supreme, and the state is a purely arbitrary geographical area charted without regard to self-sufficiency on the basis of natural resources. The city is, by nature, the child of the nation, rather than a state. The nation is, conversely, the creation of its organized cities.

A city is not just a center of highly concentrated population in which is carried on productive activities that can be operated within small areas. It cannot be considered apart from its sources of supplies and its markets. The farming regions are an organic part of the city-centered operational region. A farm is a manufacturing establishment in which food and other useful materials are fabricated from water, air and sunshine, using a self-perpetuating blueprint, contained in the planted seed.

High speed transportation facilities have altered the dimensions of our cities. A century and a half ago it took more than two hours to journey from Battery Park to Inwood, which are at opposite ends of Manhattan Island in New York City. Today an airplane trip of shorter duration starting from New York City could land a traveler in Richmond, Virginia. Perishable food products are now transported to New York over proportionately greater distances. Those intangibles, time and space, manage to function in human problems in a ubiquitous and imperceptible manner and are factors that have a very definite place in all practical problems.

Most of the city planning has been done in the past by architects. Not infrequently civic centers, populated with impressive buildings, have been the result of their efforts and from these centers have radiated avenues providing pleasing vistas. Not infrequently the vistas were more pleasing to the chief of the military police than to the inhabitants, for they provided a means whereby, with a few gun emplacements, the city could be controlled in cases of civic disorder. Paris furnishes a fine example of this type of city building. Washington, D.C., contains the same motif modified and Detroit and Indianapolis have adopted the radial avenue idea.

The rectangular street pattern is as old as Babylon, founded more than five thousand years ago. Its more extensive development took place under the direction of the Roman military engineers who built their encampments on this grid pattern. Most of these camps developed into full-fledged cities. Efficiency and economy, not aesthetics, governed the design and dimensions of the Roman camps.

The unorganized city of narrow circuitous byways and blind alleys is as old as ignorance and the daughter of weakness, fear, hatred, fighting, and cultures constricted within retaining walls.

Most of the ancient engineer-architects used at least a smattering of biological wisdom to guide them in their city planning. Some of their practices at which we laugh today, to demonstrate our superior intelligence, were soundly founded in biological knowledge. We laugh today, for example, at the utter and unfathomable stupidity of the ancient governors who kept on their staffs soothsayers who would consult the liver of a sacrificed bird or animal before proceeding with their city-building plans.

The governor of a Roman province would never choose a camp site without having his soothsayer give him prognostications from the examination of several animals, and there was a very good reason for so doing. His engineers could sample water from surrounding streams and tell by its appearance, smell, and taste whether the water was clear and potable. His al-

chemists could supply more sensitive tests. They could add their salts and acids to the water and determine with a higher degree of precision the order of purity of the water. The so-called soothsayer, however, was a biologist and he could tell with a much higher degree of precision if the water contained infinitesimal traces of impurities which by long continued use would produce inabilities and diseases in men and which, while they might not kill or incapacitate them would lower their efficiency as fighting men. Just as the modern doctor can, by looking at the tongue, the eyes, and the inner surfaces of the eyelids, make a quick diagnosis of the cause of the patient's trouble, so the ancient soothsayer could determine by examining the color, texture, and tone of the liver and other organs of captured animals whether the soil and water of the region were pure or contaminated, or whether they were producing severe or mild illnesses in the human or animal or plant populations by causing toxic or deficiency states. Some soothsayers, of course, extended the application of their observations to situations where they do not appear to be applicable. All knowledge is not titrated out of a test tube. Perhaps our modern scientists and engineers working with a lack of, or a limited, social consciousness may be misunderstood two thousand years hence. Their technical lingo is not any more conducive to universal understanding by the average person of today and tomorrow than that of early soothsayers and alchemists.

Now, perhaps, we can return to the original purpose of this chapter by asking, "What is the nature of a city?" and seeking an answer.

A portion of the correct answer can be found by an examination of cities past and present, another portion by achieving an understanding of the nature of their human inhabitants and a final portion by correctly interpreting the direction of progress and directing activities so that they advance on that course.

We have had some discussion of biological principles concerning human beings and their communities. We can now

examine the manner in which a city, as an engineering structure, exhibits some biological characteristics, as a means of better understanding its nature.

In the simpler forms of life nature provides each individual with protection against an uncontrolled environment. In the oyster it is an external shell; in the turtle, it is a carapace; in reptiles, bony plates; in mammals, a dense covering of fur. Man constructs a shelter that is dissociated from his anatomy and which permits him partly to control his environment not only in the matter of shutting out the rain and the wind but also permits him to maintain the temperature of his immediate environs at a comfort range above or below that existing outside. The shelter provides him with protection for his artifacts and with the privacy which his high state of development necessitates. It provides means for securing undisturbed rest and for preparing food, for storing food and other materials, and for disposing of waste materials.

All of these activities are extensions of internal processes in the individual. The walls of a house are the counterpart of the skin of an individual. The skin is functional in many ways. It is not just a covering and a container. It is an organ through which heat can be radiated or adsorbed, and to this end it is well supplied with a system of piping, blood vessels which carry the body fluid to the surface where its heat can be dissipated by radiation and convection and under some conditions by conduction. If greater dissipation is required, this is accomplished by evaporation of some of the body fluid. The skin is partly transparent and this permits it to adsorb radiation which is utilized in the creating of chemical compounds essential to the body's metabolism.

Functions of the skin are linked with the temperature maintenance mechanisms in the body whose functions are precisely adjusted to a narrow range above and below 98.6° Fahrenheit. The choice of this point is not arbitrary but determined by the joint chemical and physical characteristics of proteins and blood

serum. The body has a beautifully functioning thermostat for maintaining this temperature.

The walls of our homes are functional to but an extremely limited extent compared to the skin. Therein lie many opportunities for engineers with imagination. The thermostats that control our oil heaters and coal furnaces are mechanical extensions of the original nerve mechanism thermostats in the body. The heating of our homes by mineral fuels is an extension of the body's system of heating its structure by oxidation of glycogen, a sugar.

A ventilating system for the home, if only a window, is an extension of the body's respiratory system.

The kitchen where food is prepared for eating is an extension of the digestive tract where the food is further treated for the extraction of nutritive values. The pantry where a supply of food is stored is the analogue of the liver where the body's glycogen is stored. There are other analogues that are obvious.

The city is a pattern of organized facilities provided for the homes and for productive facilities conducted outside the home and for each of which there is a biological analogue.

One of the most important nutritive requirements of the individual is water, and it is equally important in many commercial production processes. The city quenches its thirst with water piped to every building and made available in generous quantities. Sometimes the source of the city's water is located at a distance. The ancient practice of conducting water to the city in open canals has given way in several steps to large conduits, usually provided with a system of reservoirs to stabilize supplies.

Just as in the human being, drinking water enters at one end of the polarized organism, is utilized, and is discharged at the other end, so is the water supply system related to the sewage disposal system. The water enters the city in the highest possible degree of purity and, when it leaves, its average chemical composition is only slightly changed but the change is very important.

The city must have a pantry for storing food as does the in-

dividual home. These are the warehouses and depots for storing collected food supplies in small and large units, wholesale and retail. The city must have kitchens in which food is fully or partly processed, such as meat and bake shops. It must maintain supplies of clothing, tools, gadgets, and materials for the home arts.

The vast bulk of all the material that goes into the city as consumer goods goes out, after various lapses of time, as waste material in every form from garbage to junk.

These are the services for maintaining the bodies of the occupants of the city as functioning heat engines which, with a given amount of food-fuel intake, can perform enough work not only to maintain themselves in operating condition but also to provide an essential excess which can be utilized in productive activities.

The human beings occupying the city possess the ability to reproduce themselves. The city must be provided with a population replenishment and maintenance service. This includes a maternity service, a medical service, and a burial service.

At the present time, medical and maternity services are provided by the same professional staff and in the same institution. The maternity service should be separated entirely from the hospitals. Childbirth is not a pathological situation—it is a normal physiological process. Linking childbirth with the hospital pathologies gives a totally improper aspect to the reproductive process. Maternity pavilions should be institutions providing the utmost in cultural and aesthetic as well as hygienic values. It is high time we terminated "the valley of death" chatter which comes from the tattling tongues of not-well-informed women and with which they inflict psychological injury on the minds of the young women.

Another divorce which should be effected is the separation of the sewage system bowl from the immersion bowl or the shower booth. They do not belong in the same room. Uniting them in the same room for the economy in piping costs is an indication that we have not yet emerged from the state of social poverty.

Within a wide range of conditions the body is its own best doctor, but within a still wider range disorders can develop in individuals for which professional outside aid is needed. The doctors are the health engineers of the community. The medical men of a city should be organized as the health engineering corps with responsibility not only for repair and maintenance of individuals but for prevention of disabilities and maintenance of efficiency and comfort permitting attainment of maximum happiness by individuals and maximum stability of the community. It is easier and cheaper to prevent than to cure diseases.

The spiritual and cultural aspects of the individual must be materialized in the city. Just as each individual will have in his home a niche for meditation in which he can get in tune with the cosmos, a collection of books from which he can derive knowledge, inspiration, or entertainment, and a corner in which he can indulge in music, art, creative activities, or helpful hobbies, so must the city contain a magnification of each of these interests crystallized into individual institutions such as churches, schools, libraries, music and art schools, community workshops, theatres, observatories, research institutions.

All of the foregoing services of a city have a direct association with the individuals in the community and with the extension of their bodily facilities in their homes, and the extension of the home facilities into the city organization. All these institutions are organs of the living entity that is the community and the physical structure, the city, that is its body.

It is the task of the engineer so to design and construct the city that it is a functioning organism on a supra-vital level and not a heap of hamburger hardware decaying in its own chaos and fit only as a habitation for mangy maggots and round-shouldered ants.

The relationship of the biological mechanisms in the human body provides the engineer with the basic knowledge upon which to build the blueprint for the living city. The relationships between city-institution organs and human-body organs

should be interpreted from the biological viewpoint and not from an immature viewpoint of economic expediency. When the relationships are properly interpreted they will be found to be in accord with the principles of engineering efficiency and, therefore, economy in cost and operation. When a city is so engineered, the architect will encounter the minimum amount of difficulty in making that city beautiful in any environment.

No city can provide out of its own natural and human resources all the materials required for designing, constructing, and maintaining itself. It should provide out of its population and environment the maximum amount of talent and timber, food and fabrication, steel and stone. The remainder must be obtained from other cities. Other communities with unique relations to particular resources may be able with greater economy to provide lamps and lipsticks, books and bassinets, violins and vitamins. The totality of things which all cities can provide is the substance of the existing state of civilization. The proper distribution of them is as essential to the welfare of the nation as the proper distribution of blood to all parts of the human body. Every city must engage in production or service activities.

Production activities, however, must be completely isolated from the organic structure of the city which is the magnified counterpart of the living individual. Injecting production activities into the organic city would be as sacrilegious and as unphysiologic as cutting off a man's hand and welding a wrench handle to his ulna or using women's bellies and backs as advertising billboards.

Mechanical and chemical mechanisms of production no matter where located are a part of a systematic process nationwide in extent and organic in nature but on a level different from city organization. A production or manufacturing area should bear the same relation to the city area as a man's tools in his workshop bear to his body. They must be convenient to reach but several dimensions from his body so they will not interfere with his freedom to move.

A production area has no right to have lower aesthetic values than the organic city area, and it carries every responsibility not to create any unhygienic factors. There is no excuse for a smoke-belching stack, a foul-smelling factory, or a stream-polluting plant. It may seem like an immediate economy for an industry to avoid the cost of preventing the unhygienic condition, but the cost is eventually paid by the entire community.

Pennsylvania has the worst polluted air of any state in the union and the highest death rate from pneumonia. If its excess of deaths above the average for the rest of the country were charged at the rate of three thousand dollars a year for each man-year lost to the community, or an average of about thirty-five thousand dollars per individual for the average life period sacrified, and this was imposed as a tax on all establishments contributing to the pollution of the air, these establishments would find it a great economy to install smoke-consuming or precipitating devices.

A chemical organization in the South installed a new process in its factory. It was able to use the old equipment. There was a quick, heavy demand for the new product it manufactured. Great billows of white smoke floating away from its smoke stacks and on to the wings of the balmy Southern breezes attested the activity of the establishment, and the books of the concern showed a nice profit. In a short time a flock of damage suits were plastered against the company for the damage done to farms by the white smoke that precipitated some distance from the city. Paying heavy damages for white smoke would put the company deep in the red and the situation looked black. The owner of the company was very much of an altruist and a man of vision and he saw a silver lining to even a white cloud. Instead of giving his cloud away broadcast he decided to keep it. With a relatively slight change in his plant he was able to precipitate the material in the white smoke, pack it in barrels, and sell it at a greater profit than he obtained from the original material of which it was a by-product. A social consciousness paid a handsome profit.

The production of potash as a very valuable by-product by precipitating the smoke from cement mills is an old story.

Factories that are eyesores and health hazards belong to an era of engineering ignorance and ethical evasions.

It is almost inevitable that cities, viewed as individual entities, should develop hyperthyroid types of personalities, with the equivalents of high rates of metabolism, fast pulse, high blood pressure, trigger tempers, easy irritability, snap judgments, touchy emotions, and be full of phobias. The pattern is both inflicted on the inhabitants by their city environment and created by them, and incorporated into the civic personality of their community. We have, therefore, a regenerative, reacting process.

Well-balanced, normally constituted individuals, with sensitive personalities—the type that can be expected to produce the outstanding examples of creative work in all fields—when victimized by the pathological hyperthyroid tempo and personality of the city develop what the doctors call peptic ulcers. They are really city ulcers.

Cities suffer from similar ulcers, but there are very many kinds of ulcers, produced from as many different causes. They are, in part, self-inflicted, and in part are chargeable to the whole economic tempo and environment of the nation. It is easy for ulcers to slip over into cancers.

15. SKYSCRAPERS ARE MONUMENTS TO CHAOS

MOUNTAINS are monuments to chaos and so are skyscrapers. Tremendously vast amounts of energy were expended by nature in building mountains. The mountains came when the blocks of terra firma which nature was moving encountered resistance adequate to block the movement. The continued expenditure of energy against the resistance caused the crumpling of the ground, the elevation of some portions, and the depression of others. Skyscrapers suggest similar cataclysmic movements in the social and economic environment that gave them birth.

As a symbol of engineering skill, the skyscraper is a monument of overpowering grandeur, magnificent in conception and construction, emblematic of both stark reality and soaring phantasy, with roots in the earth and head in the sky. It is an unintentional symbol of rebellion against constrictive slavery in two horizontal dimensional distortions. The social and economic forces acting on the structure as a constricting strain, forcing the skeleton to rise in the air, like mercury in a thermometer tube, are as real as gravity and could be calculated on a physical basis. They vary with the pressure on the foundation in pounds per square inch caused by the weight of the structure. The equation would be valid, however, only when conditions over a large area, such as downtown Manhattan, are integrated. Purely local conditions around a structure can mask the more generalized relationship.

What causes the height of a structure on a given unit of area to rise to stupendous heights when others in near-by regions are of normal or sometimes subnormal height? Here, obviously, is a

community cellular unit manifesting very great virility, greatly in excess of that of its neighbors. Does animate nature offer a counterpart of such phenomena? Yes, there is a type of cell in the living body that acts in this manner. It starts as a normal cell but in the course of time it acquires something that the other cells do not possess. It demonstrates that something by growing more rapidly and acquiring greater volume than other cells. It divides, or fissions, and forms daughter cells and they, too, grow more rapidly and attain greater volume and vigor than surrounding cells, but they actually lack something vitally essential.

Surrounding cells may look with envy upon these giant cells that appear so virile and healthy and are able to break through boundaries which hold ordinary cells within confines, that go out into the body fluids and absorb greater nourishment per cell through their larger surfaces. The normal cells may speculate on the basis of these early observations that if all the cells in a human being's body were enlarged in size to the same extent and all possessed the increased vitality, the human race would be changed to one composed of powerful giants capable of tremendous feats of strength and agility.

If this situation should come to pass it would be found that this dream of a fine, tall, agile giant would not be realized. The size and bulk would be achieved, but the proportionate strength and the agility would be lacking. This result could have been forecast by a more extensive study of nature. The lowly flea, with which Fido is lousy, can jump one hundred times its own height, but the gigantic elephant not only cannot jump to its own height but can only gets its forelegs off the ground as a circus feat. A bacterium can produce a new individual, doubling its original volume, in a matter of minutes; a human being requires nearly twenty years for the same feat.

The cost of maintaining large size increases more rapidly than the volume of the organism and the work output per unit of volume decreases rapidly with increase in size. The metabolic rate, the rate of living, likewise decreases rapidly with volume.

It appears to be limited by the surface area of the individual, the facility for dissipating heat. An elephant's weight in fleas has a vastly greater surface area than an elephant. The reproductive rate decreases with size. Suppose elephants reproduced as fast as rabbits? Or bacteria?

In the human body the strong, giant, virile cells that appear to be more successful than other cells present this aspect for only a short time and only under special circumstances. They become crowded, they crush other cells around them. They push out through the surrounding structure increasing in number and size. They form a substantial mass. First they crowd others, then they crowd themselves. The outer ones in the mass, bathed in the body's nutrient fluids, grow big, but the inner cells are shut off from the surrounding nutrient fluids, become malnourished and die.

The expanding mass works only for its own growth. None of its cells is devoted to the task of building blood vessels to carry new supplies of blood to the internal parts of the mass or veins to carry away the toxic fluid ashes of biological processes, or to build nerves that would make the mass a part of the organized body structure. It is within the body but not a part of it.

Within the mass of cells is a pool of dead, decayed matter, surrounded by dying cells, while the surface of the mass is covered with powerful living cells taking nourishment directly from the body nutrient fluids but passing none within. Healthy organs are put under pressure from the quick-growing mass, their operation hindered. The mass of packed cells, without structure, breaks and the necrotic material in the center spreads its toxic effects throughout the body. In a short time the body dies—of cancer.

Why should a body die when normal cells are being replaced by bigger, stronger, more virile cells?

In every cell in the body, in its genes and chromosomes and other structures of its nucleus, is a blueprint of the body as a whole written as the living architecture of the molecules that

compose this vital structure. Through this chemical blueprint every cell contains the potentiality of reproducing the entire body, of knowing the function of every organ and tissue of the body, of knowing its complete architecture. This is the expression of the cell's education. It knows when tissues should grow and, equally important, that tissues should stop growing when they reach equilibrium with the body plan. The responsibility for growth and accepting growth regulation is imposed on every cell. Under this plan it contributes its specialized service to the body as a whole to the extent required and receives the benefits of the specialized services of other cells throughout the body. Individual cells must bear a fixed ratio of size and operating characteristics to the size and operating characteristics of the body as a whole if the health and integrity of the body is to be maintained.

If a cell alters its blueprint it becomes an independent and not an organized body cell. It escapes from the responsibility to participate in the body's organized activities, to build out of itself structures which will be part of the body as a whole. It holds on to full freedom to participate, but as a parasite, in the body's nourishment so far as it is able and for such purposes as it sees fit to adopt. It chooses freedom to grow without restraint and without regard to the architecture of the body. It begets a brood of other cells, each of which inherits the power, and the individualistic doctrine, of the original rugged individualist. There is, however, a balancing penalty which must be paid for this freedom. The cells are big, powerful, impressive, original in design; the cells are a success, but the body dies. The cells ignored the primary biological pattern, but the pattern in its intangible processes brought irresistible forces into play to compel observance of its plan.

The skyscraper is a climactic symbol of a civilization of which it is a typical cell. It is, however, going to experience the influence of social and economic surgery. It is a safe prediction that the Empire State Building is the last of its race of mighty,

magnificent, malevolent, malignant megaliths masquerading as cells of organized civic communities.

Since the tower of the Empire State Building has been puncturing the cerulean vault of Manhattan's heaven, lightning has struck no other point within nearly a half mile. This is nature's way of pointing out that the influence of a skyscraper extends far beyond the plot on which its foundations rest. When the building was opened, there was no flooding upsurge of tenants. When some other giant structures of the same era, also in the midtown region, were opened, some persuasive measures were used to convince desired tenants that they wished to occupy floors and suites in these buildings—and when big business organizations do the persuading, the arguments can be very convincing.

When business organizations become seated in a given area they possess inertia and if it is desired to bring about their translation to a newly developed location, it is necessary to expend a very definite amount of energy to provide the momentum that will start their migration to the new era. This is merely a well-recognized technique of business and real estate engineering whose processes could be expressed in terms of the kinematics of the mechanical engineer.

A skyscraper like the Empire State Building, without a comparable structure within nearly half a mile, is a minimum civic evil, but in the downtown area of New York, with the world's greatest density of cloud-puncturing structures, skyscrapers have become poison to each other. The building of skyscrapers in that area has diminished to almost the stopping point. There are many sites remaining which would provide adequate foundations. They remain unused. The density of skyscrapers had become too great.

If all ethical considerations, and all the principles of biological hygiene, translated into terms of community life, were to be considered, the complete plans for a structure such as the Empire State Building would call for clearing the area of all other structures within a radius of not less than nine hundred fifty feet.

Purely aesthetic reasons demand such a surrounding plaza. As a street-level spectacle within that area the Empire State Building is a total loss. It is unseen above its lower floors by the pedestrian on Fifth Avenue, or on Thirty-third or Thirty-fourth Street, in its immediate vicinity. With an open plaza around it the architects could do something really interesting with the design of the structure.

More important, however, if the surrounding area were cleared the Empire State Building could be filled to its capacity with tenants without increasing the burden on street traffic and transportation facilities to a point beyond the normal for that region, and would not be creating demands for such facilities beyond those of other average-size buildings occupying equal ground areas.

If such a plan were adopted, the Empire State Building could have been placed astraddle Fifth Avenue with a design befitting this position. If this were done, the skyscraper would be taken out of the malevolent, malignant megalith classification, but it would still suffer the evils of exaggerated extension of the vertical axis.

Failure to have observed these larger responsibilities in connection with the downtown skyscrapers is what caused these enclosures-of-elevator-shafts to become toxic to each other. Adequate civic facilities could not be provided, even at excessive cost, to service the density of population they created.

As examples of engineering skill, our skyscrapers stand as monuments to the finest, most courageous manifestations of human achievement. They have not, however, been given a setting worthy of their magnificent character.

Picture New York with its skyscrapers distributed with a uniform distance between them, each set in the center of a plaza with a radius equal to the height of the building, with the surrounding area developed in architectural harmony with the central structure. If this were done, the necessity for the present excessive height of the skyscrapers would disappear. Emancipated

architects could transform such structures into cathedrals of commerce.

Because of its high density of developments, of population, of facilities, and of traffic, all well in excess of what a civilized civic area should bear, New York's Manhattan, in many of its areas, has become an elaborately exaggerated, elegant slum. Eventually the elegance will vanish.

Exorbitant land costs are, of course, the cause of the densely packed buildings and populations. This evil is regenerative. The higher the land cost the greater the density of population a building is required to house to return a profit on its cost. The greater the density of population in a neighborhood, the higher go the land costs for other buildings which forces them to house more tenants. Enforcing the plaza plan, or some other effective plan for limiting population density per unit area, could stop this tightening spiral.

Even the purchasing of land went on a skyscraper basis at one period. Negotiations were under way for the sale of a small Wall Street plot.

"To buy that plot you would have to cover it with silver dollars," said the owner.

The purchasers made a quick calculation and arrived at a figure for the plot on the basis of approximately one hundred twenty-five dollars per square foot, but his offer was promptly rejected.

"You will have to stand the silver dollars on edge," declared the owner and the deal was closed on that basis.

The cost of tall buildings would become prohibitive on the plaza plan so there would be no more skyscrapers. It is, however, merely an extension of the present stepback plan which causes upper sections of tall buildings to recede from the building line in a regular sequence as height increases as enforced in New York and some other cities. It would carry the stepping-back down to the street level.

It may be found cheaper in the end to abandon New York

City than to reconstruct it on socially and economically sound principles, and on a correct biological basis. It is a civic dinosaur. It has too much bulk to exist on a sound biological basis. It would be better to break it into one hundred separate cities and have more than half of them transplanted in other parts of the country.

There are many ways of testing the validity of an idea. Mathematicians have found the *reductio ad absurdum* technique very useful in geometry. Reducing the situation to an absurdity, it can be applied to the skyscraper problem. All living entities, be they trees or human beings, can propagate without creating a phantasmagoria of absurdity. Let us, for the moment, endow skyscrapers with the status of natural entities with reproductive possibilities. Now let us imagine that during the night while the New Yorkers were sleeping their skyscrapers, ignoring the commercial rivalries of their owners, made love to each other and cohabited and begat, and begat, and begat, bringing forth offspring, reproducing themselves at the rate of one a year.

Imagine the Empire State Building raising a numerous family and populating every successive block in the neighborhood making a canyon of Fifth Avenue and of the side streets in the thirties; the Chrysler Building doing likewise and creating a double file of architectural spear-topped lancers marching down Lexington Avenue; Candler and Lincoln Buildings alternating themselves across Forty-second Street; 500 Fifth Avenue duplicating itself until it was also 501, and 600 and 601, and 700 and 701, etc., and incest taking place at Rockefeller Center until its plato-faced, slab-sided Goliaths occupied every square in the fifties, east and west and invaded the entire area of Central Park!

At first it might seem like a very practical idea to have self-reproducing buildings in a city. Farmers use the idea with everything from seeds to sows. What a really nice profit would be returned to a builder if his twenty million dollar skyscraper would duplicate itself a year after it was built, and repeat the performance in each succeeding twelve months. After a while, how-

ever, it might become apparent that too much of a good thing is more than enough.

Equally intriguing are the artistic possibilities of the situation. It could be assumed that in time a mixing of the breeds would take place. Suppose sometime, under the urge of a balmy spring and an encouraging moon, the skyscrapers should stage a real old-fashioned Dionysian festival, with all Bacchanalian privileges prevailing, and the following year there was born on Columbus Circle an architectural melting pot marvel with the Grecian feet of the Penn Station, the hips of the Empire State Building, the flat-bellied torso of 50 Rockefeller Plaza, with a McGraw-Hill Building green band down the center, a neck of the gold-layered Grand Central Terminal Building, and the pin-pointed head of the Chrysler Building. There are other combinational possibilities that suggest themselves. The idea is more than intriguing—it is frightening. It might be well, just as a precaution, to have all of our skyscrapers sterilized, just in case. . . .

The foregoing idea is not too fantastic. There is a touch of reality to it which can become apparent if we run the picture of metropolitan progress at a high enough speed. We see the Grand Central Station development beget the multi-storied Hotels Commodore, Biltmore, and Roosevelt, and the massive Graybar Building; and this colony begets the Lincoln and later the Candler, Chrysler, and 500 Fifth Avenue Buildings, and all in turn beget the Rockefeller Center colony and its satellites. Buildings do beget buildings, even though the process is economic rather than biologic. Perhaps if we understood the economic processes a little better, we might find that they have very definite biological aspects.

Not different from the New York situation was the development of the south "prairies" of Chicago when that area was fertilized by the World's Fair and the University of Chicago, thereby leading to a spectacular lake-front development. And note what the gilded nabobs of San Francisco started when they sought Olympian exclusiveness on top of the geological pimples, called

hills. They spawned expanding colonies of sycophant satellites at successively lower levels until the areas today possess the population density and other characteristics of ant hills. This is a nice example of social and economic biology at its worst.

Quite apart from the levity in some of the foregoing paragraphs, there is a serious side to this subject. It leads to the conclusion that a thing so seemingly static and inanimate as a building has a real and radiating personality, and this phase of it and its economic and social effects extend far beyond the property lines of the area on which it was built. The architect and builder each put something of himself into the structure. It takes on, too, something from the nature of its occupants. It tells much of the nature of the community of which it is a member and is a contributor to the nature of that community. Buildings form communities in which a sense of organization can be detected, and a community of buildings has a personality just as much as an individual structure. What sort of edifice does a community of buildings attract as a newcomer to its precincts? This will be determined largely by the community of buildings, but its effects will be modified by a variety of factors ranging from the pressures of the surrounding areas to the generalized economic and cultural conditions of the country as a whole. These effects work in both directions. Almost invariably there is a very close relationship between the nature of the human social group and the community of buildings it occupies. In the vast majority of cases, however, the buildings fall far short of the ideals of those who occupy them, economic factors usually preventing full realization of ideals.

In some areas in some cities, there is apparent an excess of architectural expression which may manifest the ideal of a small but very potent strategic group, and may not be in harmony with the general population; may, in fact, be above and beyond them to such an extent that its beauties are not appreciated.

There are hundreds of vistas in New York that prove beyond a shadow of doubt that the city is not real, that it does not have a

material existence but is merely something one is seeing in a dream. One wonders what kind of hashish the architects mixed with their India ink when concocting such a cosmopolis. It can belong only to the realm of those experiences that come to one during the buzz stage at the pinnacle of a cocktail party. And how New Yorkers, native and adopted, love it! Like a cocktail party to end all cocktail parties; it is a city to end all such cities.

16. LOWDOWNS ON HIGHWAYS

"THREE steps down and turn to the right" is just as much a part of the national communications system as the Lincoln Highway. It could, depending on viewpoint, be called the transportation system. Trails, paths, lanes, roads, highways, streets, avenues, boulevards, super-highways; bridges, tunnels; creeks, rivers, lakes, bays, seas; rowboats, barges, ferries, ships; airplanes; feet, shoes, carts, horses, automobiles, trucks; railroads; viaducts, dams, pipelines; transmission lines; telephone lines, telegraph lines, newspapers, postal system, radio, television;—all of these belong in a single broad category. They are part of a transportation system, our facilities for moving objects, or items of any kind, from one place to another.

The principle of our whole transportation system is built into man himself, and practically all members of the animal system. By permitting the act of transportation to bridge many generations, even the members of the vegetable kingdom are provided with auto-transportation facilities since trees and plants, through their seeds, are able to migrate over long distances.

In the living organism we have highways of various kinds. The digestive tract is a traffic artery; the blood vessels are highways for transportation of special commodities. The living organism grows and as progressive development takes place the highways grow not only in length but in diameter. This growth is necessary in order to handle the greater amount of food and products of metabolism that pass through the system. The necessity for the expansion of the body's highways is obvious. Extension takes place in length and cross-section and also in the number of the smaller vessels, the capillaries, which remain standard in size.

Communities remain fixed in location. They expand in area and they grow in height. Building lines become fixed and the width of streets between building lines become permanently limited. The city grows but the arteries through which the life processes move remain fixed, producing effects analogous to those experienced in arteriosclerosis in the body. In the case of piping systems, higher pressures can be applied to the fluids transported, causing them to move with higher velocity and thus proportionately increasing the capacity of the lines. Cities, however, can suffer from hypertension, just as individuals do. It is not a life-lengthening situation.

Most of our modern large cities have copied their street plans from the ancient Roman camps whose dimensions were adequate for chariot traffic. Except in volume, vehicular and pedestrian traffic had changed but little in the intervening two thousand years, until the advent of the motor vehicle at the beginning of the century.

A fundamental far-reaching change in the life process or metabolism of our communities, local and national, has taken place as a result of its street and highway traffic going on a self-powered basis. A motor truck occupies less road space than a horse-drawn vehicle of equal cargo capacity and it can move very much faster. At higher velocities, however, safety demands greater space between vehicles. This offsets, with a deficit, the saving in road space achieved by a motor truck having greater cargo capacity than a horse-drawn vehicle. The net result is that the original cargo capacity of the street moves more rapidly than under earlier conditions. This is true providing the carrying capacity of the street has not been reduced by excessive parking or bottleneck congestions.

The swifter movement of motorized traffic is equivalent to putting a fluid under higher pressure. If the orifice of the pipe is reduced by rust, or other deposits, the benefit of higher pressure is not experienced as the carrying capacity of the pipe is decreased. Parking, which reduces the traffic capacity of a street,

is equivalent to the obstructing deposits in the pipe and thus robs the street of all the benefit it should get from the motorization of traffic.

If motor vehicles had not been developed New York City would have died of traffic stagnation by 1925. The benefits were temporary. The treatment imposed additional burdens by speeding up the metabolism of city activities and thus threw greater traffic burdens on the streets. Switching to motor traffic was equivalent to increasing the capacity of the streets by a fixed amount and thus gave a definite but fixed amount of relief, but the burdens balancing this relief were not fixed but growing at a rapid rate.

Unless additional relief of large magnitude is obtained immediately, the rigor mortis, postponed since 1925, will set in not later than 1955. Civic necrosis has already set in in a number of areas.

Other cities are in exactly the same situation. Traffic conditions in Boston are abominable, they are frightful in Philadelphia and shameful in Chicago, despite its subway freight delivery. St. Louis lacks even adequate controls. The problem of New York today is the problem of other cities tomorrow morning and more fortunate ones the day after.

If New York City disintegrates, the result is the work of its citizens who believe it is quite all right for them to extract benefits from municipal situations which others should be too patriotic to expect; and of city administrations which find it more expedient to temporize with problems instead of solving them—selfishness on one hand, cowardice on the other. Both are deadly factors in the organic life of a community.

Any city that handles the major phases of its traffic problems through the police department and traffic courts instead of through its engineering department is suffering from traffic intoxication, engineering anemia, civic constipation, atrophy of planning, sclerosis of the streets, mercantile malnutrition and commercial congestion and is, in general, a moribund munici-

pality with deterioration and decay descending on it to hasten its demise.

The biggest bodies are made up of tiny atoms. Gigantic problems are made up of a multiplicity of individual situations. Every city resident wants, and has a right to expect, reasonably clear streets for the rapid, safe movement of his own car or trucks, and city administration has the responsibility for providing such a situation. Every citizen, however (the exceptions are a minor fraction) uses an uptown street space for parking his car in the evening and overnight, and in eight to ten hours of downtown parking during the day uses from one to five parking spaces. The truck owner can't get away with overnight street parking for his vehicle but in the course of the day his truck may use in excess of half a dozen parking areas. The owners' business is in an average loft building, with less than 100 feet street frontage, which houses a dozen firms, each with one or more trucks. Each business has two or more persons in it who desire to park their passenger cars in front of the buildings. These cars are used in connection with the manufacture and shipping of goods originating in the building. To supply the business enterprises with the raw materials for operations and necessary services, an equal number of trucks and passenger cars must arrive at the building and park for a period. Building maintenance operations produce their share of traffic.

All those who have a business in the building expect adequate parking space for their passenger cars and trucks and for the visiting cars and trucks of concerns doing business with them. This would require provisions for parking spaces for 24 trucks and 40 cars, and these vehicles, if lined up along the curb, would require 1,400 lineal feet—but the building frontage provides only 100 feet. There is only half as much street mileage in a city as there is building frontage. With figures such as the above, as an average, each 100 feet of street length (buildings on both sides) provides 2,800 feet of vehicles. If the streets were absolutely clear of parked vehicles so traffic could move in four

columns, each 100 feet of street length of such buildings would produce a traffic procession 700 feet long.

There are many areas in New York which provide traffic congestion at this rate. Fortunately there are other areas which produce minimum traffic demands. Demands for street use now exceed street capacity. The obvious difference in street capacity utilization by one-, three-, ten-, and twenty-story buildings, with equal street frontages, is the obvious clue to the problem. The higher buildings are civic cancers. Radical civic surgical engineering is the solution for existing situations and a vastly different planning viewpoint for city planning is the solution for future development.

Rockefeller Center in the heart of the midtown congested area of Manhattan is entirely free of parking and self-produced traffic problems. This vast skyscraper colony has been designed with some sense of social and civic responsibilities. All incoming and outgoing traffic is handled entirely on a subsurface level which extends under all the buildings in the area.

The two great railroad terminals, Grand Central and Pennsylvania stations, handle their traffic entirely within the ground area of their buildings and contribute nothing but free-moving traffic to the city streets. What an amazing contrast is found in the needle trades district of the west side where the sidewalks and the streets are the shipping departments of the business enterprises in the loft buildings! There is a complete and deplorable lack of a sense of civic responsibility in this and other sections of the city. Such areas are usually in harmony with the ethical concepts of their inhabitants in their business and personal relationships.

This situation has been discussed at length to bring out the fact that the Rockefeller Center, Grand Central and Pennsylvania Railroad enterprises are typical of projects that have been engineered. The city as a whole has not been engineered and, with fortunate wonderful exceptions, has not been respectably architected. This city, with the world's greatest aggregation of

engineering and architectural genius within its borders, exhibits in itself the truth of the aphorisms, "The nearer the church, the farther from God," and, "The cobbler's children have no shoes."

The subways saved the city from dying of congestion at the beginning of the century but since then have been one of the greatest factors in increasing the congestion, because the city did not take steps to hold population densities at the level for which the subways provided a remedy. More subways, more density, until the foundations of Manhattan in the congested areas is so wormholed that there is hardly room for more skyscrapers to stick steel-supporting pillars down to bed rock. The city can't afford and doesn't dare try to impose their cost on the real estate developments that made them necessary and that achieved the benefits.

Manhattan Island has a probable automobile population of local cars and trucks, plus the constant number of visiting vehicles, of about one million. If surface parking space is to be provided for all of these cars at the rate of two hundred square feet per vehicle, a total area of two hundred million square feet would be required. This is equal to eight square miles. It seems as if all of these cars seek to crowd into the area below Fifty-ninth Street. This southern half of Manhattan has an area of about twenty square miles and the traffic which tries to move into or through it in the course of a day would require for simultaneous parking forty per cent of the total area. Fortunately they are not all in the area at the same time.

Folding this required parking area into multi-storied parking garages may, like other relief measures, produce a temporary benefit and later an increased burden—unless restrictions are imposed on population-density-increase factors. The same can be said of installing a subsurface freight subway as in Chicago. Los Angeles is, very wisely, adopting a population-density-control plan.

The streets of New York are a part of the national highway system and what is true of them is true of all other city street

networks. The highways are part of the generalized transportation system. The entire system is a mechanism for distribution of goods or service items produced in excess in one area and required in other areas.

In the past, concentrated cities were easily defended. Today, with the atom bomb as a threat, the attitude toward concentrated cities is changing. It would take a great many atom bombs to destroy New York City to the Hiroshima level, but even a few could so disorganize and demoralize what they did not destroy that the city would become a national liability instead of an asset. This would be equally true of Boston, Philadelphia, Baltimore, Chicago, St. Louis, Washington, or any other center.

Some hysterical minds, and many rational individuals with the propaganda value of the suggestion in mind, are proposing that cities be placed underground. Our present type of large, highly concentrated city has unquestionably reached the closing phase of its usefulness and it would be economically profitable and militarily expeditious to abandon it. If, however, we handle our affairs in such a way that it is necessary to build our entire national structure in a form that is proof against the atomic bomb, it is probably not worth our while to undertake the task. However, continuation of the irrational manner in which we have built our national structure will in the course of a few years produce retardation of progress equivalent to the damage which would be done by an atomic bomb in a few seconds. Inadequate economic theory can, by slow, imperceptible changes, shatter a city as effectively as a ton of uranium would do it in a few seconds, and it actually is doing so.

Our highway system is the network which weaves our cities, towns, villages, farms, and homes into a national organism. It is the equivalent of the system of blood vessels in the body which keeps the living organism in a state of nutritional equilibrium. The functional operations of the two are very similar. The diseases of the two systems are analogous.

Our highway system, for example, frequently suffers from

arteriosclerosis, or in a more common term, hardening of the arteries. This condition does not develop alone. It is always accompanied by other conditions, or symptoms. The so-called hardening of the arteries of the body is caused by deposit of fat on the surface of the arteries which becomes covered with a thin coating of calcium. This causes the size of the internal passageway through the arteries to be reduced in diameter as layers of iron rust constrict a water pipe. The parts of the body served by the partly closed artery suffer from malnutrition and they do not function satisfactorily. Legs can't climb steps they formerly did and don't walk so well and sometimes they stop walking entirely. The malnourished parts send signals to the brain for more blood and the heart pumps harder than ever to try to force the traffic line of the life-sustaining fluid through inadequate quantities to the suffering region. The heart is overburdened and becomes enlarged. Blood vessels not adjusted to the increased blood pressure may break with such possible results as apoplexy, if the rupture comes in the brain. The kidneys, with their vast numbers of tiny filtering tubes extremely sensitive to blood pressure changes, are damaged. The digestive system is upset and the individual suffers from a continuing loss of strength.

The financial aspect of the real estate situation in cities, the loading of property with synthetic values, too well known to require discussion, is the analogue of the fat deposits that line the arteries, causing congestion in these principal streets and highways. The rest of the analogy is obvious from the foregoing discussion.

A city suffering from traffic congestion is not responsible to itself alone. Every city is an organ in the national living organism and its chief responsibility is to the national organism. The city structure that supplies the nation's steel, or the one that supplies the city's bread, cannot, of its own volition, refuse to function and is under a responsibility to operate in the most efficient possible manner and to the fullest necessary extent. Of

what net benefit is it to the nation to have the production cells in the Minneapolis–St. Paul wheat city produce generously and efficiently, if the transportation system within the city is so inadequate that the produce cannot be distributed?

Railroads are highways, privately owned roads with public responsibilities. We have beautifully designed and efficiently operating locomotives, a compliment to our mechanical engineers, but we do not have a railroad system engineered as a nationwide organism.

If we had a national engineered railroad system we would not have the chaotic complexity of railroad ramifications that intermeshes Chicago into an introverted steel porcupine. What Chicago needs is a Hercules who will lop off the hydra-heads of multitudinous terminals and fashion a unified railroad transportation system—and let the contagion spread throughout the country. New York City is monopolized to a major degree by three railroad lines. Others are halted on the west side of the Hudson. This is not good system-engineering from the national organism viewpoint.

A four-tracked New York Central is good for New York State. How can we justify the single track lines for two-way traffic that strangle traffic in other sections of the country which would be benefited by further development? Our railroad system is underdeveloped to a dangerous degree, but it is a rare railroad, if any, which could sell a ten-million-dollar stock issue to the people of the United States for expansion. Yet we spend two billion dollars for a few atomic bombs. Our entire railroad system is capitalized at less than twenty billion dollars.

A little of the engineering viewpoint is needed in the manipulation of our national economy.

Our aviation industry is passing through the same phases of growth and development as did the railroads—generously fostered as military adjuncts without regard to how they will fit into the national economy. The railroads were richly endowed with empires of free, or extremely cheap, land along their rights

of way. Air lines would not profit to any great extent from this technique.

Pipe lines for transporting oil and gas are highways of a particular type. The wire tracery of transmission lines that span townships, counties, and states are highways for electrical energy. Engineers are most meticulous in their precise calculations of conductance and resistance factors on pipe lines and transmission lines, and in achieving designs that will reduce losses to a minimum in the traffic passing through these highways; but no one takes the trouble to reduce to systematic presentation of formula and equation the transient and long-term factors that produce congestion and resistance in city traffic and, therefore, losses.

The electrical engineers use a phrase, "wattless current." It describes a condition in which a lot of energy is consumed, a lot of heat produced, but no work done. There is a lot of wattless current in social and economic structures and in our municipal mechanisms. One of the greatest developments in man's efforts to control electrical energy and apply it to his use was the discovery by Nikola Tesla * of the polyphase system of alternating currents. Alternating currents pulsate in rhythmic fashion sixty times a second. Tesla combined in one of his systems three such currents so that their pulsations were equally spaced in time, or had equally separated phases. At any given moment the wires of two of the phases were acting in the return circuit for the current flowing in the third phase. Each circuit had a chance to be the supplying phase one hundred twenty times a second. The number of wires required to conduct a given amount of electrical energy was cut in half.

There may be a useful suggestion in this system which can be applied to city engineering problems. A human being or community is like an alternating current. An alternating current rises to a high positive value, drops to the zero point, then moves

* *Prodigal Genius—The Life of Nikola Tesla,* by John J. O'Neill. Ives Washburn, Inc., New York.

to a high negative value and back to the zero point in each cycle and passes through sixty cycles in a second. A human being in his activity rises to a high positive or productive value during the day, goes into a recreation, or zero, period in the evening, and then goes into his high negative value, or sleeping state, at night.

The human organism has a frequency of about thirty cycles per month, or 365 per year. Its activities may be divided into three phases— (1) Obtaining needed materials (2) Operating on these materials to obtain its own life energy and using this energy to operate on materials to produce an excess of products which it can (3) Distribute and exchange for a new supply of raw materials for starting again with the first phase.

In the daily life cycle of a city we try to crowd all three phases into a single eight-hour period, and quite naturally the streets and all other channels of our transportation system are hopelessly overburdened. If we should apply Tesla's three-cycle system to our community life, we would divide the twenty-four-hour days into three eight-hour periods. In the first period we would operate the supply phase—bring into the community the materials it requires for its productive and life activities; in the second, the productive activities would operate; and, in the third, the distribution of materials produced.

From 9 A. M. to 5 P. M., the commercial, mercantile, and manufacturing area of the city would be in full swing, engaged in productive activities; from 6 P. M. to midnight, the trucks could appear and cart away the goods produced; from midnight to 7 A. M. the trucks could bring in the materials needed for the day's activities. Under such a plan the various activities would not be in conflict with each other for right of way; the peaks of each activity would be separated in time.

Even such a plan as this would not be of any use to a city which is a hodgepodge mess of disorganization in its every unit of area. Cities must be planned so that the least necessary amount of co-operation, of the type which imposes wasteful restrictions on

the individual, is required. On the other hand, unless full individual co-operation is given, the best plans can fail.

New York City adopted a modified and limited form of this plan since this chapter was written, requiring truck deliveries to be made before the 8 A. M. traffic rush started, utilizing the period between midnight and 8 A. M. in which the streets were previously almost entirely free of vehicles. The experiment provided some relief but was far from a complete success. It demonstrated that the limited capacity of the streets was far from being the only bottleneck which could impede the movement of goods.

Truckmen were asked if their situation had been improved. The consensus of their replies was:

> Instead of waiting from eight A. M. to four P. M. to deliver goods, we now start waiting at midnight and we don't get finished any earlier. We arrive earlier but no one arrives earlier at the business houses. The business houses don't open for business until eight, and if someone does arrive earlier to receive the goods, what good does that do when the freight elevator doesn't start operating until eight? And even when the freight elevator is operating earlier, there is a line-up of trucks waiting and before your turn comes, the regular morning rush period starts and you are stuck again.

IT IS quite obvious that the elevator service in the individual buildings is a part of the unified transportation system of a city. Inadequate storage space in individual plants preventing the keeping on hand of sufficient amounts of raw materials to permit the uninterrupted flow of manufacturing operations in spite of irregular arrivals of materials, and also for the storage of the manufactured products, is an important, though not very obvious, link in the transportation system. New York City has no barn, no pantry. It lives ninety-six hours from starvation.

Space in city manufacturing area buildings is expensive, because of high rents which trace back to high building costs and high land costs. Adequate space at reasonable cost just does not exist. It becomes apparent that an economic system which kites

land and building costs is also a factor in the operation of our transportation system.

An unsolved problem in any field of city life cascades its effects into every other field and everyone pays part of the penalty, the total amount of which may be far greater than is apparent when the original cause alone is considered.

17. CONSTELLATION OF CITIES

CITIES ARE constructed by engineers. They are not designed by engineers, however, nor by anyone. They just "growed up." The engineers who constructed them were hired employees and not directing executives. The coming era calls for courageous city planning with architects, biologists, engineers, economists, scientists, and sociologists on the executive planning board. It is going to be necessary to build a brain into the cities, provide them with a built-in pattern of development, a growth-limiting, and to organize all cities into a single national super-city.

A city in its actualities is something very different from a city as defined in legal statutes. The bricks and boards in which a community lives are not the city, but bear a very intimate relationship to its inhabitants. The individual home is an extension of the body of the occupant, or occupants—snails and turtles carry their apartments around with them. The collective structures of a city are the home of the organic community which inhabits the city.

The earliest comprehensive handbook which has come down to us on city planning and city building was written by Vitruvius Pollio (better known by the former name), a Roman architect and engineer, whose writings (*De Architectura* *) are undated but whose contents indicate he lived in the first century B. C. His professional activities were in full swing during the reign of Caesar Augustus (44 B. C.–9 A. D.) who declared he changed Rome from a city of brick buildings to one of marble palaces.

Modern engineers need not feel that Vitruvius was too far behind their times to be of interest to them. It is only during

* Loeb Classical Library, Harvard University Press, Cambridge, Mass.

the past hundred years that modern cities have caught up with the Rome of Augustus. The Romans had city water supplied in their homes, municipal sewage disposal, hot and cold water showers, bathroom fixtures which would feel right at home in the showrooms of the American Radiator Company, central heating systems, and five-story elevator apartments.

Vitruvius could have taken a job as City Architect and City Engineer for New York City, Washington, Boston, Philadelphia, or Baltimore, up to 1880, and would have been able to condemn the conditions he found as far below the standards that had been achieved in Rome, and these were not very high. He would have been able to give all these cities a new, progressive start, freeing them from slavery to the unimaginative English school of architecture. Up to this 1880 period he could, from his Augustan experiences, have worked wonders in London, Berlin, and Paris.

All of the cities mentioned were still in the stone age up to the beginning of the century. The early puffings of the steam age, and the first faint flickerings of the electrical age, had, at that time, almost no effect in changing the character of the cities. They were still built of brick and wood. Steel was used to only the slightest extent.

Large areas in all the American cities mentioned still carry buildings which were in use in the period when Vitruvius, Caesar's city planner, could have felt uncomfortable because of our civic backwardness. In the construction since that time, the availability of cheap steel, the coming of electricity as a convenient source of energy, and increases in the supply of energy available have brought about mechanical and physical improvements in building design, but we are continuing to build the same style cities with every fault and weakness in them magnified as a danger to the extent that we have increased the population density per unit area.

Building a modern electrical-energy city on the foundation of a horse-age city is less sensible than installing the motor of a Mack ten-ton truck in the first passenger car that Henry Ford

built and expecting it to survive for a useful period. Cities must be redesigned.

The Hindus many centuries ago cut into mountains and carved out of their substance magnificent subterranean temples. They were carved in places where suitable mountains offered the right kind of opportunities for making the carvings, but the locations bore no useful ecological relationship whatever to the location of populations that might avail themselves of the temples. They carved their temples where suitable rock structures were available, not where the people lived. Today the temples are neglected, and in ruins.

We have no grounds for taking a superior attitude toward the Hindus of the early centuries who fashioned these temples. Many a business and many an industry is today tying itself to a Hudson River, a New York Bay, an Erie Canal, a Boston Harbor, a Delaware River, a Chicago stockyard, or to a San Francisco Bay, a location to which it bears only the slightest economic or social relationship.

Many a clustering relationship that may have had some redeeming aspects in the days of slow and inadequate transportation is being continued with total disregard of the fact that progress has brought about its emancipation. On a basis of ease of communication between them a business organization in Los Angeles is closer to a business organization in New York today than were two organizations with offices in the same small building in New York in 1880, before the days of the universal telephone. For personal visits, Chicago is five hours away from New York and the Pacific Coast an overnight trip—like one man in New York saying to another late in the afternoon, "I'm busy tonight, I'll see you in the morning." Radio gives instant coverage of important news to the entire country.

This tremendous change in communication facilities, coupled with the equally vast change brought about by opportunities to travel made possible by the railroad, automobile, and airplane, has completely altered all spatial and temporal relationship.

Space and time are not what they used to be. The Lincoln Highway is Main Street in the super-city of the United States. The super-city does not now exist nor could it be satisfactorily organized out of existing cities. It will be created out of a vast array of new cities created and located on a long range national plan. This national super-city which is, essentially, the nation itself, reconstructed and rejuvenated, can be planned and built for a useful life of one thousand years, and more. What a task for the office of an engineering organization! There is not, however, a single such organization in the world today prepared to handle undertakings of this type and magnitude. Engineering is an art based on all sciences but it has not been adequately developed. Some of the essential progress has not yet been started. We can, however, start the project and the desired knowledge will be acquired as we proceed. This is a practical procedure. We learn about life by living. The lower floors of the Empire State Building were completed before the plans for the tower were drawn.

Engineers are faced with the task of developing the technique of city planning, and that includes everything from details of a home, details of local communities to details and overall plans for the mechanisms of production, utilization, and distribution systems, under a sound economic system, on a national basis, with an understanding of their ramifications throughout the world. The world itself will be visualized as an international super-city. "Engineer" is used here in a generic sense. The term will include not only those now designated by that term, but economists, sociologists, anthropologists, business executives, bankers, doctors, and a host of members of other professions. They will be serving as engineers because they will use the practical engineering approach to problems.

In designing the new super-city of cities, the engineers will be designing a new nation. The cities will be the basic unitary cells of the larger organism. All cities will function under a universal plan in harmony with their nature and the nature of the national organism. Cities will be functional, and not geograph-

ical, units. They will be designed primarily in adjustment to the inhabitants, secondarily in harmony with environment, and thirdly with respect to productive activities. An agricultural, a mining, a manufacturing, and a commercial-service city could each present an appearance totally different from the others and yet be identical in their functional aspects. Rural areas will be recognized as parts of cities. Farms, ranches, and orchards are manufacturing establishments differing in no essential way from factories.

Most of the city planning which has been written about and discussed has been based on uncritical acceptances of the cities as they exist without a theory as to their nature, in structure or function, and are attempts to treat symptoms rather than find causes of troubles.

A new basis for city planning is developing. It is not at all strange that the clearest statement of the new theory should come from an astronomer, Prof. John Q. Stewart of Princeton University. He gives an excellent presentation of this new field of social physics in "Empirical Mathematical Rules Concerning the Distribution and Equilibrium of Population" * and in "Concerning Social Physics." † Prof. Stewart has had the benefit of an engineering background.

A more complete and more technical presentation of the population-density problem is given by Dr. Nicholas Rashevsky, Associate Professor of Mathematical Biophysics, in his recently issued volume *Mathematical Theory of Human Relations.*‡ Dr. Rashevsky is primarily a physicist. Two decades ago, he started to reduce biochemical reactions to fundamental mathematical equations, and soon found his technique applicable to the description of more complex biological situations.

Important contributions to the developing science of social physics are contained in the writings of Ellsworth Huntington, Clarence A. Mills, and William F. Petersen. The list becomes

* *Geographical Review,* Vol. 37, No. 3 (July 1947), pp. 460–485.

† *Scientific American,* May 1948, pp. 20–23.

‡ The Principia Press, Bloomington, Indiana.

long as the field fans out into specialties. Several very useful works * have been published in recent years.

In equations on paper, cities can exist in any magnitude from a single inhabitant to one including all the inhabitants of a continental area. The effects of cities on each other vary with their densities of population and distance from each other. No city within a realm can escape the effects of the pattern of the total constellation of all cities. Population potential gradients pervade the entire realm.

Growth curves of ancient and modern states, of population, and of territory fit into exponential curves. This has been demonstrated by Prof. Harnell Hart of Duke University. Such equations of expansion are, undoubtedly, correct (though incomplete) descriptions of the growth factors exhibited by these communities. The disintegration that takes place after the growth passes the knee of the curve indicates that such concentrations are dynamically unstable under the economic theory used. The economic energy required to maintain such institutions beyond the control point is in excess of the energy which can be derived from their operation. The destructive explosion of the uranium atom is due primarily to instability caused by concentration of a critical amount of mass in its nucleus.

As with empires, so with cities. There are stages of growth in which the forces of disintegration exceed the powers of cohesion. There is an optimum size for cities and for regional and national constellations of cities, but with a useful elastic limit. If the engineer were given a clean site and unlimited resources he could design and build a city of any dimension which would be operative functionally as far as its physical characteristics were

* *Levels of Integration in Biological and Social Systems,* The Jacques Cottell Press, Lancaster, Pa.

Human Biology and Racial Welfare, Paul B. Hoeber, Inc., New York.

The Science of Man in the World Crisis, Columbia University Press, New York.

Science and Life in the World, Westinghouse Centennial Forum (3 vols.), McGraw-Hill Book Co., New York.

Cybernetics or Control and Communication in the Animal and the Machine by Norbert Wiener, John Wiley & Sons, New York.

concerned. If this city were turned over to the prevailing type of political administration and to the prevailing uncontrolled operation of economic factors the city would quickly degenerate into a pathological state and the processes of decay would become dominant.

City planners are seeking to save existing large cities by proposing peripheral cities and suburban garden cities, to relieve the strains of congestion in the central regions. This, however, is merely acceptance of the existing situation and an admission they will continue to expand the present city beyond optimum dimensions. It is continued enslavement to mistakes of the past.

Future progress calls for wide and more uniform dispersion of the total population with a low maximum of concentration in any area, low top limits to total population and minimum distances set within which new civic centers may not be developed.

A city, as a living thing, has the right to possess and express a personality. A city of one million population can express only a multiple personality. Hospitals for the insane hold many persons with such personalities. It is doubtful if an aggregation of more than ten thousand persons can manifest a civic personality and individuality. The leveling power of large numbers is lethal to unique artistic manifestations by individuals or small groups; it is a dictatorship of the lowest common denominator in which the democratic expression of the small-group personality perishes.

Individuals are lost in large multitudes. Finding themselves frustrated in efforts to impress their desires or necessities in too large a group, they withdraw from participation in all group activities and yield their rights, responsibilities, and liberties to whomsoever wishes to take them over and democracy decays in the rule of petty political potentates. Democracy can develop and freedom flourish only in adequately engineered communities of optimum size, which must be determined on engineering, biological, and economic principles. Primary attention will

be given by the planner to the engineering and biological aspects as they exist in progressive and relatively stabilized states. Economics, as taught today, has not attained a state of equilibrium; it needs a Newton or an Einstein, who will appear when the need for him is admitted. It is apparent we prefer the danger of a crackup rather than admit present principles could be improved.

Form is a flexible factor in planning city organisms. Nature has demonstrated this in the multiplicity of shapes of her living and thriving productions, plant, animal, and human. Adequate provision is made in them for all of the organic equipment required to sustain the vital processes. The form which the structure takes permits the proper relation to each other of all the vital factors and makes possible harmonious relationship with environment. A plains community will make a different form adjustment to environment than a valley or a shorefront city.

Nature teaches us the value of both proximity and separation in the placement of organic structures. In the higher forms of life organic structures are isolated from each other but provisions are made for transportation and communication between organs. The engineered city will have its various activities isolated from each other, but have adequate communication facilities.

Production activities, the factories and workshops, will be completely separated from the remainder of the city. The city may be viewed as a polarized organism with production activities at one end and cultural activities at the opposite end with other activities strung between:

Rail and road communication center for linkage with other cities in the constellation of cities

Production, manufacturing, or service center through which the city supports itself

Commercial or business center for sales, storage, exchange, distribution, repair, maintenance, and building

Civic center for administration

Residential center

Cultural center.

It is impossible to do any intelligent city planning if there is no limitation on city area, population density, and zoning of activities.

At the present time 20 per cent of the population of the United States lives in one-tenth of one per cent of the area of the country. This is the 28,875,878 population of thirty-eight of the largest cities covering an area of 2,347 square miles. This area is 25 per cent larger than the state of Delaware. Ten per cent of the population, 14,406,589, that of the four largest cities, lives in an area of 854 square miles. One and three-tenths per cent of the total United States population lives in 31.2 square miles. This is the 1,889,924 population of Manhattan Island where the density is 61,000 per square mile, almost one hundred per acre.

The city in the United States with the greatest density of population is Union City, N.J., 43,000 per square mile. Others, in order, are Hoboken, N.J., 31,000; Somerville, Mass., 24,000; New York City, 20,000; Passaic, N.J., 19,000; Irvington, N.J., 18,000; Newark, N.J., 17,000; Paterson, N.J., 17,000; Trenton, N.J., 16,000; Highland Park, Mich., 16,000; Chicago, Ill., 16,000; Cambridge, Mass., 16,000; Lancaster, Pa., 15,000; Philadelphia, Pa., 14,000; Milwaukee, Wis., 14,000; Jersey City, N.J., 14,000; Providence, R.I., 13,000; Cleveland, O., 12,000; St. Louis, Mo., 12,000; Boston, Mass., 12,000; Pittsburgh, Pa., 12,000; Reading, Pa., 12,000; Lawrence, Mass., 12,000; Wilkes-Barre, Pa., 12,000; Camden, N.J., 12,000; Detroit, Mich., 11,000; Buffalo, N.Y., 11,000; and, Washington, D.C., 10,000.

In contrast (among the cities of 50,000 or more population) is St. Petersburg, Fla., 1,000 per square mile; Duluth, Minn., 1,400; Portland, Me., 2,000; San Diego, Cal., 2,000; Tacoma, Wash., 2,100; Cedar Rapids, Ia., 2,200; Manchester, N.H., 2,300; and Holyoke, Mass., 2,500.

These figures are not strictly comparable but they do give some indications of the nature of the cities. The cities with more than ten thousand population per square mile are utterly indefensible, for reasons previously discussed. Cities like St. Peters-

burg, Fla., have been somewhat overambitious in taking in territory and much of this is populated with hopes for the future rather than with homes and individuals, but it is a much better place to live than any of the cities with the greater densities of population. It is an old city and has grown up in haphazard fashion but population-density has been well controlled. Miami Beach is a new city, a made-to-order city, with density now at a low level, but it, too, has grown with dreams of empire and hopes for profit from real estate value increases rather than of establishing an economically sound community designed for self-support and well-ordered living from local resources. As a playground, however, it may be allowed a certain amount of leeway.

A city with an area limited to one square mile for residences and cultural and administration activities, and an equal area for production and business activities with a surrounding border one mile in width for suburban and rural development and with population limited to ten thousand may be found to present the most desirable conditions for developing organic communities.

A unit of this type would embrace a total of twelve square miles and provide accommodations for ten thousand in its residential nucleus and between five hundred and one thousand in its rural environs. The immediate rural environs could supply the major fraction of the city's requirements of eggs, poultry, and vegetables.

If all of the eighty million persons now living in communities of twenty-five hundred or more inhabitants were to be housed in new cities of this type, eight thousand such cities would be required covering ninety-six thousand square miles of land. This is three per cent of the land area of the United States and less than five per cent of the land area now occupied as farms. If these eight thousand cities were compactly laid out, they would cover an area equal to the states of Ohio and Indiana which would leave a large area for heavy agriculture. There are now six thousand communities, of two thousand population or more, in the United

States, forty-six hundred of them having ten thousand or less population. The great majority of them are inadequately located, or designed, for survival in the new plan.

Communities now located on railroads or principal highways are rarely suitably located. Nature does not run arteries or nerves through organs. She brings the artery to the organ and then bifurcates it and further breaks it down to smaller ramifications which extend throughout the organ. Location of industries or cities on railroads belongs to the era of poverty in transportation when we depended on horse-drawn drays for carrying goods. The motor truck has given us freedom of choice of location for industries. Communities located on main highways are bottlenecks for traffic and such communities become enslaved to a longitudinal growth along the highway.

A new system of high-speed passenger transportation will be designed to link the new national constellation of cities. It will be of the mono-railway type in which trains will run in suspension on elevated rails on longitudinal girders laid on the arms of T-shaped supporting columns. Mono-railroads will not be tied to roads but will run across country like electrical transmission lines and will carry passengers at average speeds in excess of one hundred miles per hour. This will be the city-linking type of transportation. The stations of these lines will not be within the cities but in their suburban borders nearest the residential zone. This system is much cheaper than subways for present large cities.

If no other considerations interfere, cities will be designed so that their manufacturing zones will be polarized toward the present type of freight railroad which will carry incoming and outcoming goods, and their residential zone polarized toward the mono-railway which will supply the passenger transportation.

It may be objected that a city limited to ten thousand population would not provide adequate manpower for some existing industrial units which employ many thousands of workers. The

answer may be that industrial units which have attained gigantic dimensions may, like the gigantic cities, be manifesting unrecognized characteristics of economic cancer which will bring about their disintegration. There is a strong probability that such is the situation. It is unlikely that there exists any industry, or service organization, now too large to be manned in a ten-thousand city, which could not, with more satisfactory results, be broken down to units which could operate in such cities. Giant industries are now going through this process. There will be constellations of related cities in which related units of industries can be located. The smaller units will bring about much healthier social and industrial relations. Many factors will be taken into consideration in determining city location and distribution of industries.

In addition to these organic units, there will be specialized national cities. There is an unfilled need at the present time for national convention cities, centers where meetings can be held by organizations that attract more than ten thousand members and guests to their gatherings. There isn't a city in the United States today that is well suited to entertain the meetings of the American Medical Association, the American Association for the Advancement of Science, the American Chemical Society, and other national organizations, not to mention the quadrennial conventions of the Republican and Democratic political parties. There would be university cities and resort cities. Each city would have a purpose in life.

Washington started life as a well-planned national city which would always be the dignified and beautiful capital of a great nation. It is, today, beautiful in spots, dignified and magnificent in some of its aspects, but the early dream of organic civic grandeur has evolved into something more like a modern municipal nightmare.

In the days when Washington was planned there was adequate space in a small city for all the existing departments of the Federal government. In the meantime, Washington has taken over

functions which the founding fathers visualized as inherent in the states, counties, and cities, and has developed foreign ramifications of unprecedented magnitude. The growth rate of governmental institutions is probably much greater than the growth rate of the country as a whole. They have expanded enormously but official Washington is strangulated by an iron ring of developed real estate and the streets that were expected to be beautiful have become overnight parking garages, and its avenues traffic tangles full of Gordian knots.

There is room in Washington for the executive, legislative, and judicial branches of the government; state departments, embassies, Congressional Library, and some of the institutions along Constitution Avenue, together with adequate hotel accommodations. The departmental activities, war, commerce, agriculture, labor, government printing office, etc., should be shifted, each to a newly created peripheral city. The Pentagon Building is on too close a periphery.

Agricultural cities will come into existence under the new plan. There is no more necessity for a farmer and his family to live on his farm than there is for a factory worker and his family to live in the factory. Farm homes can be grouped in communities. The automobile and powerized devices have emancipated the farmer from the farm but he has not become fully aware of his new-found freedom.

The new cities will be functional and beautiful. Each will have freedom to adopt the form best suited to its purpose and environment. Every city will be supplied with the most modern facilities. Houses will be built best to serve their purposes and not with economy in construction costs as the dominating motive.

Architects are not in agreement about the best street layout for cities. They have never had opportunity to design a city of standard size. They have been trying the impossible task of drawing a design which would function equally well when used in a city of ten thousand, fifty thousand, or one hundred thou-

sand inhabitants. Nature shuts off growth in bodies when they reach optimum size, and for further progress makes provision for the body to reproduce itself. So it should be with cities. Size limitation is in harmony with nature.

Nature uses many design motifs, and each one is entirely satisfactory in the situation in which it is used. It invariably provides beauty in form and color, economy of material, and efficiency in operation. Artists and architects have sought the secret of nature's design technique. Some of them feel they have achieved the golden compass, and with it have drawn series of lines, circles, squares, and rectangles exhibiting geometrical resonances, rhythmic harmonies, and mathematical magic. Each approach is different and yet they have much in common. They are like the various geometries and the cosmological theories of the scientists—each self-consistent and an accurate picture of nature within a limited range, each a glimpse of a fragment of the greater truth which still manages to elude us. The recently deceased Claude Bragdon insisted that an architect's designs must present aspects of organic unity in systematic fashion on an underlying co-ordinating principle.

The quest of the absolute archetype of artistic unity, the primitive prototype of perfection in form, is not of modern origin. Seekers of the perfect type of city in recent centuries approach the problem from many angles without success and, hunting inspiration, meander through the medieval period, and swing farther back to make contact with Vitruvius of the Caesars and then parade through Plato to Pythagoras.

Pythagoras (about 580 to 505 B. C.) was the father of the engineering approach to scientific research as opposed to the introspective method. He believed in making experiments to determine how much truth a theorem contains, making accurate measurements and recording numerical results. He reached the conclusion that the solution of all mysteries can be achieved through mathematical analysis.

This Greek philosopher had nothing but contempt for both

rulers and people who continued to use violence to settle problems instead of employing Pythagorean wisdom. Eventually a fire was built in his honor—with him inside it, accompanied by a group of his disciples. They had become too powerful to be handled in any other way.

Pythagoras believed in keeping knowledge secret. All knowledge was to be memorized and passed on only to disciples after long initiation. He required that any records made were to be written in symbolic form which outsiders could not understand. He belonged in that group of modern scientists who conceal, rather than reveal, knowledge in their publications.

Pythagoras described the "music of the spheres" which was his symbolic way of referring to the harmonic mathematical relationships that exist between the distances of each of the planets from the sun. In recent centuries we re-discovered the relationship and call it Bode's Law.

The architects such as Ictinus, designer of the Parthenon, who gave us "the glories that were Greece" and the engineer Callicrates who built it, were Pythagoreans and were adept in the mathematical relationships taught in the lodges of this master of experimental science. They did not commit their knowledge to writing but incorporated it in the designs of temples and other public buildings which remain even today in the top rating among the most beautiful monuments ever erected by man. Another Pythagorean was Phidias who took the sterile gold of the philanthropic Pericles and with it gave to Athens an architectural glamor and to Greece a golden age.

It is probable that Pythagoras acquired his secret of the science of form from the Egyptian priests during his studies in the Nile valley, and that they in turn acquired it from the Sumerians in the valleys of the Tigris and Euphrates Rivers. At any rate the secret of the master builders passed from the Greek to the Roman world and from the Roman to the Gothic world, becoming more highly diluted with them, and finally appearing as a trace element in modern civilization. If we wish to go beyond

possibilities and probabilities, and demand absolute knowledge of this secret of the master builders, we may have to be satisfied with the dilute trace that has come down to us, as discovered in the writings of modern investigators, and decide that this is all of the secret that ever existed. Uncritical acceptance of all theories, and complete skepticism concerning their validity are the two extremes of all possible attitudes toward them. The more reasonable intermediate attitude is to test the theories and, if useful, use them without regard to their origin whether ancient or modern.

The chief presentations of the theories are to be found in the works of Jay Hambidge, *The Elements of Dynamic Symmetry;* Matila Ghyka, *The Geometry of Art and Life;* and Robert W. Gardner, *The Parthenon—Its Science of Forms* and *A Primer of Proportion in the Arts of Form and Music.* These works contain extensive references to the rich literature of the field.

Dr. Gardner, recently deceased, former professor of architecture in New York University, developed his theories along the most practical channels. His basic pattern is a series of inscribed and circumscribed circles and squares. He found evidence of its application to plan and elevation of the Parthenon and the city of Athens, other Greek and Roman temples, the Gothic cathedrals, Versailles, Paris, the city of Washington, D.C., the national capital buildings, many bridges, monuments, paintings, sculptures, Greek vases, and artistically printed pages, as well as to the human figure and the solar system. Cleveland Rodgers, author of several books on city planning and a member of the Planning Commission of New York City, was first interpreter to the public of Dr. Gardner's theories.

Lacking anything more basic, this system presents many aspects of usefulness in connection with design of cities, buildings and even mechanical contrivances. Professor Gardner limited his presentation to claims that the pattern is useful in testing the designs achieved through other techniques. It is apparent that artists, architects, and other creative individuals, use this or some

other closely related technique, but in a subconscious process, when they make free-hand drawings of artistic conceptions, for such free drawings when satisfactory in an artistic sense exhibit the mathematical harmonies credited to the ancient masters. If this is so it appears to be a case of excessive professional coyness not to bring the mathematical design-pattern into use on the conscious level from the very beginning of the process of creative design. It limits creativeness to no extent whatever. It supplies a bridge that spans the chasm now existing between artist and artificer, architect and engineer. It supplies some evidence that the realm of art is an organic part of the cosmos, that beauty is a blood relative of mathematical harmony and that emotional surges in response to beauty are understandable in terms of physical resonances.

There are surges in our individual lives and in our national existence. Fully understood, they would be found to be describable in terms of the dynamics and physical characteristics of the organisms be they human bodies, cities, or nations. We are in the critical phases of a cycle at the present time; we may be in the state of national puberty and entering on a new adult phase of life. In this stage nature reconstructs the operational processes in the body.

A new engineered nation that is an organic constellation of cities, each of them a living organism, may be the form for which the conditions of the new age call. Reconstructing our cities would be in line with the change to adolescence in nature. We would be building for the longer, creative, mature age that lies ahead.

Perhaps nature found it necessary to pass us through the mad experience of bombed cities and easy destruction of the highly concentrated production facilities whose continuous operation is so essential to the existence of complex civilizations. It is difficult to find any other credit item to be chalked up in favor of the recent manifestation of manic behavior. The cost of that destructive deviation from normal human behavior would have been

sufficient to pay for reconstructing our cities and their means of communication. If rational thought processes will not lead us to sensible planning, perhaps our irrational fears will accomplish the result. The cost of our adventure in world imperialism and of our role as dictator of national political ideologies on a terrestrial scale, if applied to internal reconstruction, would create such social and economic stability here and abroad that world markets would cease to be a problem, and political ideologies different from our own would vanish as threats.

18. GADGETS

CITIES are constructed of gadgets—airports, avenues, apartment houses, bricks, boards, bridges, bathrooms, beds, buffets, boulevards, canals, chords, clearing houses, dams, derricks, disposal plants, escalators, earthenware, electric lights, fish markets, filing cabinets, glasses, germ killers, golf courses, heating plants, health departments, hedges, implements, incinerators, institutes, juke boxes, jars, junior high schools, kitchens, kettles, knobs, lampposts, lumber yards, link belts, motors, machines, masonry, nozzles, nuts, nickel plating plants, partitions, paving bricks, power-houses, quadrangles, queen-posts, quarries, radiators, roofs, railways, reservoirs, sidewalks, sewers, skyscrapers, steam engines, steel mills, tanks, tables, tools, traffic lights, used car lots, ultraviolet lamps, ventilators, voltmeters, vacuum cleaners, wells, water supply systems, wire gages, xylophones, X-ray tubes, yachts, yardsticks, zones, zoos, zinc plants, and zipper and zither factories. If the alphabet were longer many more such items could be listed. With every item of the complete list there is an engineering association. It is the task of the engineer to build the things out of which cities are built.

Under the prevailing classification, city building stays within the field of the civil engineer, but a city is such a complicated organism that every discipline in the field of engineering is required to make a contribution to build a city and keep it operating.

What are the limits of civil engineering? At one time it included all engineering that was not military engineering. Naval architecture split off as a separate discipline, then mining, mechanical, steam, electrical, and these into a host of sub-classifica-

tions, and new departments were created in pace with technical progress. There is no longer a clearly defined line that separates any one department from another. They all merge into related fields in every direction. There is, actually, just one engineering discipline—ENGINEERING—and no one is a master engineer who is not satisfactorily informed concerning all of its ramifications.

The engineer is building a very complex technical civilization with the very complex city as its chief monument. The direction of real progress, however, is toward simplification. Both movements are in operation. The engineer is called upon to implement and mechanize the complex cities, and, of necessity, a more complex gadgetry is produced.

In order, however, successfully to occupy and maintain the new areas of progress a population competent to handle the new situation is required and if such competence is not available, the gadgetry must be simplified to bring it within the range of the population. This is one of the reasons for the simplification of gadgetry. The other reason is that good design demands continual simplification. In order to achieve simplification, it is invariably necessary to acquire greater knowledge. Complexities are almost always an indication of a lack of adequate knowledge.

Machines, or structures, which today stand as monuments of glorious achievement because of their size or complexity may be looked upon tomorrow as evidence of a lowly evolved state of our technical development.

A steel plant contains a rolling mill a block long, a roaring mass of machinery, a Goliath of mechanisms, from the exit end of which there issues a strip of steel, as wide as a man is high, at a speed of five thousand feet a minute—a mile a minute. In spite of its gigantic proportions and its tremendous velocity this machine operates with a precision as great as that of a fine watch. Building and operating this device involved all engineering disciplines. We can be proud of this stupendous and prodigious monument today. What will be our attitude ten or twenty years

from today? We can ask the same question about the modern newspaper press which consumes forests faster than a forest fire.

Steel is a beautiful metal. It is almost as versatile as a smart wife. When a real job is to be done, steel is the stuff and gold is a tramp. Yet the handful of gold we produce each year has almost the same dollar value as our steel output. The nearly 90 million tons of steel output of our gigantic mass-production process stand as a tribute to the skill of our engineers. The greatest growth of the industry was attained during a period in which there was very little scientific research done as a foundation for progress. It was rule of thumb and brute strength engineering. Without the use of calculus we produced good steel and plenty of it. A lifetime spent in making and loving steel enabled the man of fifty to learn through his eyes alone almost as much as the man of twenty-five today can learn with his spectroscopes and other instruments. Research is now bringing progress at an accelerated rate.

Steel will hold the major portion of the metallurgical field but other metals are seeking to build up some specialized corners for themselves at the expense of steel and also at the expense of wood which is rapidly reaching the stage at which it is becoming a scarce commodity. Other metals are not sufficiently plentiful in nature, at low cost of extraction, to compete with steel. High-grade ore is being depleted at a rapid rate. A major job for engineers of tomorrow is to get the iron out of the low-grade ore cheaper than we now extract it from the high-grade ore.

Rock is the cheapest material in nature. We use a little of it as a building and road making material, as cement and concrete. A smaller amount we cut by slow, expensive methods to produce building blocks. When energy, and therefore heat, becomes cheaper we may be able to imitate nature's processes in melting rocks and rolling and shaping them into forms in which, on a mass production basis, they could compete with lumber as a material for building homes. Perhaps a method may be developed for treating on the spot the sand or rock excavated at a

building site and melting and pouring it for walls, floors, and roof. Such a process may not be practical now but engineers are going to find themselves forced to do a lot of original thinking in the not too distant future. Use of local materials cuts down transportation burdens and is a step toward making local areas more independent economically. Use of cheap cut or molded rock would be in line with the need for greater simplification in building construction, particularly home construction.

Homes, if existing trends continue, will become too expensive for ownership or occupancy. It may be necessary to find a substitute for them. We may be driven to living in sub-surface homes, involving minimum material and construction costs as a modern version of the cave. A more practical solution may be an engineering job on some of our economic, rather than our building, processes. There is much to be said in favor of the present type of above-surface house.

There still remains to be done a tremendous job of home engineering. The home is the common module unit of the city. Tomorrow's home will be a powerized unit. The facilities will be built in, not installed piecemeal in hodgepodge fashion. Heating, cooling, air conditioning, refrigeration, vacuum, electricity, water, sewage, garbage disposal, laundry, cooking units, germicidal lamps, radio, television, telephone, will be considered part of the house—not extra cost auxiliaries. Rooms will be of generous dimensions. There will be ample storage space. Radiant heating and cooling will be built into walls and floors. If an alloy can be produced at reasonable cost that will conduct heat as well as, or better than, silver, the heating will be done by direct transmission of the heat by conductivity through solid metal from a central source. Another method would be imbedding semi-conductors in the walls and passing electric current through them to produce heat.

We have been so glamorized by electricity that we lose sight of the fact that it is still possible to use other techniques to yield power. A current of air moving through a single tube will

transmit energy in much the same fashion as a cloud of electrons moving through a pair of insulated wires. There are many household, hand tools such as egg beaters, cream whippers, meat grinders, dough mixers, that could be powered by a small air jet turbine set into operation by plugging a tube into the vacuum or pressure outlet.

Our methods of cutting stone today differ in no essential way from those which prevailed when the pyramids were built. Except for the top surfacing of concrete our roads are essentially those built by the Roman engineers and they probably merely improved the techniques used in Troy centuries earlier. Our mechanized methods of building roads would, however, amaze the Roman engineers. Construction projects in Rome were carried on with slave labor. The Colosseum, for example, was built by slaves captured by the Roman army in its conquest of Jerusalem. Almost all ancient engineering structures in the Near East cities and empires were built in this way.

The social and economic structures founded on slave labor were the primary cause of the failure of earlier engineers to develop natural power sources, and labor-saving devices. The political executives of those early cities and states were firmly convinced of the soundness of their economic theories that you can't go wrong taking a profit in the form of free labor of the slaves. It practically paid the cost of the army, too, since the soldiers received their chief pay in the form of slaves. Slaves were, in addition, essential to national welfare. It probably did not dawn on these executives that a nation whose welfare depends on enslaved colonies, or a master who is supported by slaves, is the slave of the slaves. The political profits of slave labor prevented progress of civilization from the plateau it reached in Sumeria five thousand years ago and continued without a further raise in level until the fall of the Mediterranean cultures. The European feudal systems were little different. No fundamental progress was made until man harnessed natural forces to his use on an extensive scale about a century ago.

We are in the midst of setting up a new power civilization, the most obvious phase of which is providing our communities with the gadgetry that is the symbol of the new era. We are proceeding by installing un-co-ordinated gadgets in the homes of the earlier era, neither well adjusted to the other, and are not making much progress in achieving the new basic viewpoint which will reveal what the home of the future will be like. The limiting factors are economic more than technical. We are, simultaneously, seeking to bring about a similar change with respect to our cities. We will have to go on a basis of mechanized municipal housekeeping and are trying to do so in archaic cities.

Our factories are in an advanced, but not final, state of mechanization and modernization. The major task with respect to them is their co-ordination into a national organic system. This will not be achieved under any of our sophomoric systems of socialism or kindergarten cults of communism. We need something sounder in the form of a scientific democracy, something more closely in tune with the true dignity of man and of greater aid in achieving his ideals. This will not be attained, however, if the scientists, engineers, and mechanics, who are the masters of the mechanized civilization of the power age, become the slaves of pre-power age political ideals.

Agriculture is a department of our productive system—open air food factories. Our farms are in the log cabin stage of development in spite of the mechanized aids which engineering progress has made available to them. They have become greatly more productive on a per-man and a per-acre basis but they have not reached their final stage of development. Operating techniques have improved but the farms themselves are as they were five thousand years ago—still entirely dependent on the elements. How we would laugh at a chemical engineer who set in operation a plant in which water in large quantities was required, and depended on catching rain water on the roof, and if the operation required that a particular range of temperatures be maintained and he tried to accomplish this by letting the sun shine

on his reaction tanks. Such an inadequate factory would correspond to our farms today.

Farms of tomorrow will be constructed with respect to soil, its temperature control and water supply. We may have double, triple, or quadruple decked farms. Some recent research indicates that the processes by which plants built their food substances are not wholly, but only partly, dependent upon sunlight, and are related more closely to the action of an enzyme which, once it has been created by sunlight, proceeds to act independently and continuously to synthesize the food substances from water and carbon dioxide and other nutrients without further need for sunshine. We may be able to supply from artificial sources all the light that plants require and set up multilayered farms in which the ideal conditions of temperatures, moisture, and nutrients will be carefully controlled. Such a manufacturing farm would undoubtedly be in year round operation with an output of two or three crops per year and with a yield per acre greatly exceeding anything now obtainable. It could be so highly mechanized that a minimum amount of labor would be required. Under such conditions, investment in the required plant may be justified.

It is quite possible that we may, in the near future, be entertaining entirely different ideas from those now promulgated concerning the desirability of cereal foods as a chief element of human nutrition. The best that can be said about them is that they are cheap. They stand low in the list of desirable nutrients with fruits, vegetables, nuts, and meats far above them. When a cereal, wheat for example, is highly processed to make it easy to preserve in storage and more desirable as a commercial trading commodity, it loses a major portion of the elements that make it useful as a human nutrient and it is of value mainly for its calories. Wheat is in process of commercially sterilizing itself off the menu. Corn is antagonistic to some essential nutritional values supplied by other foods.

The human appetite could very easily shift entirely away from

cereals. This would have a far-reaching effect on the farm situation. We will not get away from natural foods but we are not entirely dependent upon present types of food. Seeds are living organisms and are mechanisms for producing more seeds. They work very slowly. Among cereals a one hundred to two hundred fold multiplication takes place in a seasonal cycle of reproduction. The rate of production from one planted seed is about one seed a day through the growing season, or somewhat less than one in two days on an annual basis. There are many other organisms of small size which reproduce themselves at a much faster rate. Yeast cells reproduce themselves one hundred times as fast as cereal seeds. Yeasts are rich in nutrient material, carbohydrates, protein, fat, nucleic acid, vitamins. They are but one of thousands of micro-organisms which could be utilized to produce food materials for human beings.

Some micro-organisms can utilize sterile minerals, plus water and oxygen dioxide, as their own nutrient material and convert them, in their bodies, into complex substances suitable as food materials. Other micro-organisms can convert low grade foodstuffs, carbohydrates and sugars, into higher grade nutrients. We have not begun to develop this field.

A desirable development to look forward to would be a bacterium that would take in petroleum as its nutrient material and transform it into sugars, starches, proteins, and other high grade food materials. The carbon chains of the ordinary petroleum molecules, plus the ring molecules of petroleum from the East Indies, are the foundations on which the more complex food molecules are built. In the not distant future, when we no longer have use for petroleum as a fuel, we may find it very useful as a food producing material.

Food transformations by way of bacteria are a continuous process and are vastly more efficient in time and space required than agricultural processes. This gives us one more assurance, that the danger of the Malthusian catastrophe, the situation in which there will not be enough land to provide food for the

increasing population, lies in the far distant future—if it has any real existence whatever. Instead we may find ourselves dispensing with cereals, cows, and pigs as excess food sources.

Our scientists are learning more about quantum mechanics and the vibratory activities of molecules. There is a lot of energy in light and it is energy of a particular kind. Molecules are bits of atomic architecture, vibratory structures of crystallized energy. Their architecture can be altered to a more complex design but this change usually involves work and means we must supply energy. It can be achieved quickly and directly if the energy is added in just the right quantity and dimension. Somewhere in the electromagnetic spectrum, in the range of visible or invisible light, a quantum of energy, an atom of light, can be found with just the right dimensions to assist the chemical transformation.

It is processes such as this which nature uses in making the enzymes that build food stuffs in plants. In time we will learn the detailed secret of enzymes, how they operate apparently contrary to the second law of thermodynamics, building compounds containing a greater amount of energy out of substances containing lesser amounts of energy—making up the difference with absorbed light of just the right frequencies, a chemical resonance phenomenon.

When the details of these chemical resonances are worked out we will be able to blueprint a process of building up complex food materials from simple substances faster and more efficiently than plants or bacteria are able to do it and we will gain further independence from our environment through the utilization of energy.

These developments are a bit nebulous at the present time but it is likely that in a matter of a few years, perhaps months, the vanguard of projects involving bacterial food production, and chemical resonances,* will be appearing in engineering offices. The first major change in agricultural engineering will

* Just before going to press confidential advices were received that such a chemical resonance pilot plant is in operation.

then be under way. The farm will present a different picture than at present. Its relationship to the production activities of the rest of the nation will be more clearly defined.

Those who will carry the burden of making plans for the immediate future which will be in harmony with the development of the next thousand years are going to need a tremendous reserve of imagination and access to a tremendous fund of knowledge. All the forces of nature will mobilize themselves to advance a plan which is headed in the right direction for the future.

19. POWER FOR LIFE IN THE FUTURE

THE PLANNED civilization we have projected for our immediate future will be powerized by energy from the nucleus of the atom. That which we now use comes from the planetary electrons surrounding the nucleus. We discussed in an earlier chapter the structure of the atom and how the sun supplies itself with energy by converting about four million tons of its substance into radiation every second. What we are interested in at this point is the problem of providing man with nuclear energy power plants, directly under his control, on the earth, and the effects which this development will have on our plans for an engineered structure of civilization.

We have staged five bomb demonstrations of release of nuclear, also called atomic, energy from the heaviest elements, uranium and plutonium. In each of these demonstrations an amount of the heavy element was consumed, in a process called fission and in which the heavy element is split into two lighter components and some smaller fragments and part of the mass of the heavy element is converted into energy. The amount of the heavy element consumed in each bomb was somewhere between one ounce and one ton. It is illegal to possess more specific knowledge.

No data, based on measurements, are available concerning the amount of energy released in these demonstrations. To this extent our knowledge of the input of material and output of energy are in perfect correspondence, matching each other like two zeros, but the data is not every helpful from the engineering viewpoint. Another perfectly matching zero is our knowledge of the cost per pound of the material used.

Government spokesmen have expressed the desire to aid in

developing the uranium-plutonium processes for civilian use as a source of energy. To this end, a "pile" of uranium, or plutonium, is being set up at Brookhaven, L.I., N.Y., under the direction of a group of physicists. The essential information concerning it still remains secret and it is likely to remain so for a long time. This technique of secrecy may be a new and practical method for securing the co-operation of the entire engineering and scientific profession but the process by which the goal will be achieved is not clearly apparent. The situation, however, is not too bad, and it may be very helpful in bringing about a much more satisfactory development of the atomic energy situation because other elements possess much more satisfactory properties than uranium for power production purposes.

The uranium group elements when fissioned yield about two and a half million times as much energy as coal, or oil, on an equal weight basis. The figure is not exact, nor are the two processes exactly comparable. If the figures are given in comparable units we get data of this sort: Energy given out per atom of carbon burned in oxygen, about four electron volts; energy given out per atom of uranium fissioned, approximately two hundred million electron volts. On a per-atom basis the uranium process gives fifty million times as much energy as the carbon burning process. The uranium atom, however, has a mass of 239 atomic weight units and carbon 12, so that on an equal weight basis the ratio comes down to two and a half million.

There are many other atomic energy processes, scores of them, yielding various amounts of energy. All of them yield less than the uranium group on a per-atom basis but some of them yield much more than uranium on an equal weight basis, the latter involving the very light weight elements.

Lithium, with an atomic weight 7, when fissioned yields 17.28 million electron volts of energy which is 8.5 per cent of the uranium yield on a per-atom basis. Uranium, however, is 33.5 times more massive than lithium so that on an equal mass basis the lithium process yields 580 million electron volts, or 2.9

times as much as uranium. This is 7.25 million times as much energy as released from the burning of an equal weight of pure carbon in oxygen.

These two maximum-yield processes give such tremendously great energy outputs that processes giving intermediate yields are totally lacking in glamor.

If the uranium process had not developed in such a spectacular manner or, better, had not yet developed, and we had not yet discovered the lithium process, but instead had gotten busy back in the thirties developing a process then known, we would have had our imaginations staggered by the information that we could, by a nuclear energy process, obtain thirty-three thousand times as much energy from coal as we now get by burning it. The yield is possible by bombarding carbon with the nuclei of heavy hydrogen atoms.

Among the first eight elements, the ones lighter than fluorine, there are now known at least twenty-six atomic energy release reactions of which ten give a higher yield than uranium on an equal mass basis, three give about an equal amount, eight give more than half as much and five give less than half as much. The carbon process gives the lowest yield in this list.

There are two general classifications for all of the atomic energy processes—chain reaction and non-chain reaction. In the chain reaction process an atom is split by the impact of a bombarding particle such as a neutron and the fragmentation of the atom produces among the debris one or more neutrons which act as bombarding particles and shatter other atoms in a continuing process. In the non-chain reaction process the original bombarding particle, a proton perhaps, shatters an atom but the fragments do not contain a proton or neutron which can continue the process automatically. There must be a continuous supply of these particles from outside sources to maintain the atom splitting process.

It is obvious that the chain reaction is essential in a process in which all of the atoms in the entire mass of material are to be

disintegrated instantly with the sudden release of the total amount of energy that can be made available, as is necessary in the case of explosions. It is equally obvious that a chain reaction explosion would not be desirable in a power-house devoted to constructive activities.

In the non-chain reaction process the reaction continues as long as bombarding particles are supplied from an outside source and to the extent to which such particles are supplied. When the number of bombarding particles is reduced, the amount of energy released is reduced and if the bombarding particles are cut off the energy release stops. This type of process is ideally suited to constructive and peacetime processes. The rate of energy release is always under control and can be stopped instantly and the furnace is no more dangerous than a pile of ashes.

In the chain reaction pile such as is being built by the government scientists at Brookhaven, and has been used elsewhere, the "furnace" contains a large amount of one of the uranium elements, the same as the material used in the atomic bombs that dropped on the Japanese cities. The amount of uranium is believed to be measured in tons, perhaps one hundred to one thousand times the amount used in a bomb, but definite data are not available. The construction method that has been used provides a solid lattice of such a material as carbon or graphite to slow down to their effective speed the cloud of chain reaction neutrons. In the holes in this honeycomblike lattice, rods of uranium encased in aluminum are inserted. The extent to which the uranium rods are inserted in the lattice controls the operation of the "pile." If the pile gets too hot, or the cloud of neutrons begins to get too dense, the uranium rods are withdrawn. In the bomb the explosive chain reaction takes place when the density of the neutron cloud reaches a certain critical value. The Brookhaven "pile" is undoubtedly extremely carefully engineered to provide maximum certainty that the excessive neutron density state will not be reached and that the rods will be withdrawn

sufficiently in advance of the danger stage to insure safety of operation. Nevertheless the fact remains that there is accumulated in one spot a relatively great amount of the most tremendously explosive material to be found anywhere in the universe.

Less than five miles from the spot where the Brookhaven "pile" stands a bolt of lightning struck a tree in the village of Yaphank some years ago. The author, in line with his duties at that time, investigated the effects of the lightning bolt. It struck a tall tree, shattering it down to the roots. Jagged shafts of wood were thrown distances up to two hundred feet. In the farmhouse, about two hundred fifty feet from the tree, a sheetmetal kettle became so hot it fell apart at its soldered joints. Nails used in building parts of the house became so hot that they charred the wood and could be pulled out by the fingers.

The question naturally arises— Can a chain reaction pile be so carefully engineered that it will be guarded against the freak effects of lightning? The first bomb that was set up on the tower at Los Alamos, New Mexico, for testing is reported to have been exploded prematurely by lightning.

In all engineering procedures, safety is the first factor to receive consideration in designing structures, plants, or mechanisms. If a project offers opportunity to use either of two substances, one a violently unsafe material which will give a yield of 100 per cent, and the other a safe material that will give a yield, relative to the first, of 290 per cent, which would the engineer recommend? That is the choice that faces the engineer of today in the matter of designing atomic energy plants for the future. This choice would eliminate the dangerous, explosive uranium and select lithium which is free from the danger of chain reactions and gives the higher energy yield. Scientists are reported to be unwilling, for safety reasons, to operate the uranium pile beyond a low, inefficient, level of operation.

To this must be added other considerations. In the uranium process there are emitted by the exploding atoms showers of

neutrons which, if they penetrate the human body can render its atoms radioactive and are selectively deadly to the white blood cells which protect the body against infectious diseases, and there are given off by the atoms, in addition, blasts of high energy radiation more penetrating than our most powerful X-rays. Very heavy shielding, by great thicknesses of lead, must be used to cut down the neutrons and X-rays. In addition the fragments of the uranium atoms are highly radioactive and some way must be found of disposing of them.

In contrast the lithium process produces neither neutrons nor radioactive material to be disposed of. Radiation is either absent or of a minimum amount. The lithium atom, with atomic weight seven, is bombarded with proton, atomic weight one, which unites with it momentarily forming an atom which explodes and yields two helium atoms. Helium is the well-known light gas which is famous for the fact that it is chemically inert, can't burn, and for this reason has been used instead of the inflammable hydrogen in filling the gas bags of dirigible airships.

The fact that the lithium process is of the non-chain reaction type is very much in its favor from an engineering viewpoint. The fact that it will proceed only at the rate determined by the amount of bombardment used is analogous to the operation of our present type of coal and oil burning furnaces in which the combustion is controlled by draft regulation. The burning takes place at the rate at which air is supplied. This is so much more practical than pulling out a grate full of hot coals which are threatening to reach the explosion point—which is the analogue of the uranium control method.

Lithium is cheap whereas uranium, prepared for use in a "pile," costs, according to not well-documented estimates, about twenty-five thousand dollars a pound so if it is used by the ton the cost on this basis would be fifty million dollars a ton. These estimates, however, have never been accompanied by factual data and may be utterly fantastic.

Very inadequate data are available concerning the operation

of uranium piles as sources of power. The little that has been published can be found in the official report *Atomic Energy* by Henry Smyth * and *The Science and Engineering of Nuclear Power,* by a number of authors, edited by Clark Goodman.† McGraw-Hill Book Company is planning a series of books on the subject and now issues "Nucleonics," a monthly publication.

The operation characteristics (based on a very limited public knowledge and which may not be reliable) are not encouraging. When the heat from the furnace is transferred by water, the temperature of the water just reaches the boiling point 100° Centigrade (212° Fahrenheit). When the heat is transferred by air, the furnace reaches a temperature of 150° Centigrade (302° Fahrenheit). In view of the fact that the temperature of the exploding uranium atom is well up in the billions of degrees these operating temperatures are fantastically low. It is an indication of the extremely low level of activity to which the pile must be limited. These very low temperature gradients recall the effort of Georges Claude to extract energy from the temperature differences between the hot surface water in tropical seas and the cold water drawn from the ocean depths.

The heavy weight uranium process requires an entirely new kind of furnace and the intervention of heat transfer units, while the processes using the low atomic weight elements may be used in connection with present type furnaces with relatively slight changes. At least this approach can be used in the experimental stages and out of the early experiences may come a particular design of furnace best suited to the processes. These experiments should be made regardless of their outcome.

It is easy to visualize a practical preliminary approach being made with an experimental plant in which the basic operation is coal or oil burning, just as it is carried on in our present powerhouses. On this can be superimposed a nuclear energy process. A start could be made with the carbon process which gives a

* Princeton University Press. Princeton, N.J. Sections 8:36 ff. and 8:43 ff.
† Addison-Wesley Press, Cambridge, Mass.

very low yield, only thirty-three thousand times as much energy as from an equal weight of coal.

In the lithium process a simple furnace would be used, perhaps in conjunction with a mercury boiler, depending on the temperature experiences with an experimental plant. The furnace would consist of an airtight chamber into which a number of beams of protons, or ionized hydrogen atoms, would be projected by ion accelerators. Each would be a simple tubular arrangement perhaps fifteen feet long. The chamber would hold lithium vapor which has a melting point of 186° Centigrade and a boiling point of 1,224° Centigrade.

The high speed proton would strike the lithium atom and break it into two helium atoms. These would fly out of the lithium atom in opposite directions at speeds in excess of twenty-five thousand miles per second. If they succeeded in reaching the walls of the boiler, they would transmit their kinetic energy to it by impact, which would be transformed into heat, or would rebound to strike other atoms and impart some of their energy in each contact. The energy of the flying particles would thus be distributed uniformly through the vapor and transmitted by the vapor to the walls of the boiler in the same manner in which the gases of combustion heat the walls of the boiler tubes. If one ounce of lithium atoms are split in this manner, the energy released will be equivalent to that which would be released by burning 235 tons of coal.

Since no experimental plants have been built, anything which is said about the lithium process as a practical power-house technique is pure speculation. The speculation, however, is based on rigidly controlled laboratory experiments which demonstrate that the rate at which the lithium atoms will be split will increase in proportion to increases in the velocity of the bombarding hydrogen atoms and that there are some favorable resonance points.

In the lithium process it is quite probable that the temperatures could be made very high, as high as the metals can stand,

which is the reason for suggesting a mercury boiler. Or perhaps diphenyl may be useful for heat transfer from the furnace to a separate boiler. It is probable that the lithium furnace could be made as small as the heat transfer problem would permit. It may be found desirable to maintain a relatively low density of lithium vapor in the furnace, perhaps of the order of less than an ounce per cubic foot of furnace volume. These prognostications, and that is all they are at the moment, are in strong contrast with the experiences with the uranium piles, their tons of fuel, their low levels of activity, and low temperature gradients.

The current policy of maintaining secrecy and a government monopoly of the uranium group materials and processes are hindering the development of these processes, and this may be the most desirable course. It may be a blessing from the wisdom of ignorance if it results in throwing the development of the power processes using the low atomic weight elements into civilian hands where it belongs.

Another trend is hindering the development of atomic energy and that is the attitude of the political powers in Washington. The public utilities are not in the good graces of the political powers; they are scheduled to be kept under rigid control. The stated reasons are that the utilities have in the past engaged in questionable procedures in their financial manipulations and in their efforts to acquire political control in regions where they operate. The real reason for political anxiety concerning the public utilities is based on the fact that control of the energy sources of the nation gives control of the nation. Reasonable government control is highly desirable, but monopolistic control and its use to suppress the development of an industry are totally indefensible and inexcusable, regardless of what grounds are offered as justification.

There is nothing politically unhygienic in the fullest possible development of the electrical power industry to meet all existing energy needs of the national community and to provide a reserve. The utilities have done an excellent job in building up

such a system. As an engineering achievement it is one of the brightest pages in human history and the electrical, steam, mechanical, hydraulic engineering professions to whom credit is due for this accomplishment are entitled to all possible direct and indirect support and encouragement that will aid them in continuing and expanding their work. It is their natural and rightful responsibility to develop atomic energy for the enhancement of public welfare and this task must not be hindered by any battles for control between political and financial groups which have always been contrary to public welfare.

It is unquestionably true that no single utility group could have undertaken such a gigantic project as the Tennessee Valley development under the conditions prevailing at the time it was started by the government. The engineering talent which provided the planning and construction was not a unique property of political powers in Washington; as a matter of fact, this talent was drawn from the public utilities field. The financing of such a gigantic project was something which the political powers could swing by utilizing government resources over which they had strategic control and which was not available to the utilities industry. In procedures such as this the tax collector becomes the executive, which is an extremely dangerous situation. In the organic viewpoint this is equivalent to the stomach, because of its strategic position in receiving the entire nutrient material for and on behalf of the whole body, taking advantage of the situation to administer the digestive processes for its own benefit.

There is nothing essentially evil, however, in such developments as the Tennessee, Missouri, and other river valley projects. The important fact is that the progressive development was accomplished and the populations of the areas will receive constantly increasing benefits which could not otherwise have been made available to them. They are, perhaps, teaching a much needed lesson to the public utilities about the wisdom of directing all operations toward the goal of public welfare and that this

is the primary purpose of all operations, not the will of financial manipulators.

An important aspect of the government's entrance into the power production field needs to be considered in connection with the development of the atomic energy field. Every new development is considered a competitor of existing institutions. The government is committed to gigantic hydroelectric projects in its river valley developments. Atomic energy power plants will, in time, make the government water-power developments archaic or at least subsidiary. The chairman of the Atomic Energy Commission was formerly chairman of the Tennessee River Valley Authority which could be considered no more than an assurance of a smoother transition from the hydroelectric to the atomic energy eras rather than a step by the political powers to seize atomic energy as a government monopoly.

If political control of the nation's power, as a means of complete control of the nation, is to be continued it is essential that control of the atomic energy system be obtained before it is born. There is no doubt whatever about control on a national basis being desirable so that this new energy agent will be directed entirely for the general welfare of the people. There is, however, a big difference between government control and government ownership and monopoly which in these days of dictatorships could become extremely dangerous. It would be unwise for the government to hinder the development of atomic energy to maintain the dominance in some areas of its hydroelectric developments. It will be discovered that, under good executive judgment, full and free development of the atomic energy field in the hands of the people can be fostered without damaging existing institutions.

It is desirable, therefore, for the government to throw open the development of the atomic energy field to those competent by training and experience to develop it. This should be done without the slightest regard for so-called security necessities—they are figments of the minds of monomaniacs and warmongers.

Twenty-five years from now we will look back and be amazed at the idiocy of some of the pet foibles of some of those now in positions of power.

If our present antediluvian methods of administering international relations continue, we will need a much more extensive energy source than now exists. We were caught short of power when we entered World War II. The dim-outs in cities were imposed on us not because of any danger of air raids. This hysterical excuse was merely a means of further enslaving us to fears conjured out of nothingness to deepen our national psychopathic state in the interest of military mastery. We were short of electrical machinery. The dim-outs were imposed so the consumption of electricity would be reduced to permit the removal of dynamos from the cities to new factories making more or less necessary munitions of war.

Making immediate provisions for vastly expanding our energy sources to meet any new suddenly expanding situation should be item Number One on any program of planning for the future, and the way to do this is to encourage the most widespread investigation into means for developing atomic energy projects.

Atomic energy developments will have to be tied in with our present power projects. If uranium processes are used the atomic energy power-houses will have to be located far from centers of population because of the dangerous radiations and the inherent danger of cataclysmic explosions even though the latter may be carefully controlled to the greatest possible extent. This will be a handicap. If the lithium process is used there is no radiation and no by-products of any kind. The generating station will not require a smokestack. A power-house could be built to look like a Greek temple in a city's public square. Perhaps it would be a good idea so to treat our atomic energy power-houses as this would accord them a suitable recognition of the part they will play in our community and national existence.

We may later find ways of producing electric currents directly from nuclear energy reactions by transforming mass directly into

a stream of electrons but for quite a long time we will use the energy in the form of heat with which we will generate steam to operate turbines to drive our dynamos. In our immediate program these installations will go into existing power-houses.

In connection with the new city type program a different plan of development will be used but the transition will be made from existing installations. Generation of power from atomic energy sources will, of necessity, have to be carried out under a national scale plan.

Under high density of population and heavy consumption conditions in New York City, it is practical to distribute steam for heating from a central plant but it is unlikely that such conditions will be widespread in the future. Energy will be distributed in the form of electricity. Small plants for generating electricity are not efficient. It will probably be found more desirable to economize on man power than to seek highest efficiency in generating station equipment. Small stations are less efficient in the use of man power so it is probable that large central stations will supply large areas. Where severe weather conditions threaten power line interruptions, it may prove desirable to maintain local power-houses even though they may be less efficient than larger centralized units.

A more uniform distribution of population and of industries will require, and permit, a different type of power grid than now used. The linking up of widely separated power-houses by long distance transmission line is called a power grid. Generating stations will have more geographical freedom than at present since fuel transportation and ash disposal problems will be eliminated. It may be found cheaper to have a larger number of stations thus reducing the need for longer transmission lines. Nevertheless, it may be found desirable to tie local power grids into a single national grid as a safety precaution and for load equalization.

This grid, powered with nuclear energy, will be the productive life force of the nation. The amount of current drawn from it

will be an index of the metabolism of the national organism. Before the power era each individual, using his own muscles, could expend in productive effort the equivalent of 270 kilowatt hours of energy per year, equal to the work he could do laboring eight hours every day in the year. This, plus the work of horses, and a small amount of energy from water and wind mills, was all we had available for maintaining the processes of individual, community, and national life.

Today each individual in the United States consumes, or has consumed on his behalf, 1,660 kilowatt hours of electric energy, equal to 4.8 tons of coal and 13.1 barrels of oil per year, all used in industry or in such services as transportation, heating, and lighting. When reduced to the common denominator of personal effort each individual has available through these power sources the equivalent of the labor of thirty-seven individuals.

It would be expected that as a result of the consumption of this amount of energy our standard of living would be thirty-seven times higher than in the pre-power era. We do not have any system of units by which to measure such conditions. It is obvious, however, that our standard of living has not been raised to such an extent. This is understandable, however, for the national organism is a biological mechanism and is not a perfect converter of food energy into productive work. The gasoline engine produces as work about 25 per cent of the theoretical energy available in the fuel it consumes. We cannot expect a high order of efficiency in our very poorly engineered national economic system so all the average individual should expect is a 15 per cent yield in standard of living elevation from the thirty-seven-fold increase in energy, or about a five-fold living standard elevation. This is approximately the improvement we have experienced. An electrical transformer is more than 95 per cent efficient. The efficiency of our economic system can and should be increased.

When atomic energy becomes available we can anticipate the energy consumption curve will climb to a new high level plateau.

The steepness of the curve cannot be calculated with any degree of certainty at the present time. The first change will undoubtedly be a shift from coal, gas, and oil to electricity for heating. The cost of electric current has not been advancing nearly so fast as the cost of the fuels. With respect to the cost of coal and oil as the primary fuel the cost of electricity has been decreasing. With the introduction of atoms as the primary fuel there will be both a relative and absolute decrease in the cost of electricity. The present rising costs of coal and oil will continue. Both of these conditions will accelerate the shift to electricity for heating, for cooking and its more generous use in lighting.

We consume a tremendous amount of power in our approximately forty million automobiles with petroleum as the primary fuel. Can they be shifted over to an atomic energy basis? If we try to use a uranium process the answer is a definite no. If we use the lithium process it is quite likely that this not only can be used but will permit a great simplification in the power plants of our motor cars. They would go over to a steam basis. An increase in the number of automobiles in operation can be expected. There is a lot of difficult engineering involved in such a project and much time will be required to solve many intricate problems.

It would be possible to use the small boilers which will be developed for automobiles in home heating plants but this seems an unlikely trend, except for farm homes, as the simpler electrical method will be the more popular. During a transition period we will see the installation of atomic energy boilers in such places as apartment houses or business buildings where it may not be found desirable to rip out the steam heating equipment in the apartments and offices but where the building owners may wish to get the immediate advantage of the economies of atomic energy heat sources.

Isolated mines and quarries will be beneficiaries of the new energy sources, and great changes should result in mining, ore

dressing, and ore treating, and other metallurgical processes. With large supplies of cheap energy available it should be possible to work on many ore bodies, the processing of which is uneconomical under existing conditions. In addition entirely new types of processes will become available.

Railroads will have a choice between electrification and atomic energy locomotives. Greater economies in original cost and operation will favor the latter. Railroads will be relieved of the task of carrying a substantial tonnage of coal for their own fuel requirements. They will face a constant reduction in coal and oil as revenue paying freight. Under the new long range reconstruction plan the railroads will be required, in normal operation, to move more freight than even during wartime peaks. Reduction of fuel-carrying burdens will be a fundamental economic gain. Substantial extension of the railroad plant, to provide additional freight-carrying facilities, is likely to be an early urgent necessity.

Shortages of manpower and an increasing demand for goods will necessitate a stronger trend toward the automatic factory. The welfare of the national community, and of all individuals, will require this development and it should be administered for the general welfare of the country.

The demand for many articles now manufactured will diminish and many new articles will be required. Central heating furnaces will give way to electrically heated floors and walls. Kitchen refrigerators will not contain cooling units but will be supplied with a coolant from a central plant in the basement which will provide air conditioning service. House designs will change radically, calling for new building hardware. Lumber is getting entirely too expensive for continued use as a building material and will be replaced by natural stone or artificial substitutes, preferably of local manufacture throughout the various areas.

Industries and cities will be widely dispersed and the genera-

tion of electrical energy will have to be planned on a national fully co-ordinated scale to provide unlimited supplies of this vital fluid of our national life.

It would be very undesirable to have the atomic energy industry government owned, or a government monopoly in any way. It will be a necessity, however, to make full provisions for its use on a national scale under sufficient control to insure its adequate and co-ordinated development.

We could lose all the benefits of atomic energy through the unwise administration of our atomic energy service. There is a definite attitude in some power-house groups at the present time to minimize the benefits that will accrue from its use, and to claim it will make very little change in the power situation. The attitude may, fortunately, be more strongly localized in vociferous second lieutenants than in the more responsible generals.

Under this attitude the viewpoint is expressed that since fuel accounts for about 25 per cent of the cost of electricity the use of atomic energy will merely eliminate the fuel cost and result in a reduction of 25 per cent in the cost of current. A reduction of 25 per cent in the cost of current would not make it possible to raise the national economy and our standard of living to a new high level by an amount comparable with that which resulted from the coming of the power age. In a quarter of a century we have had the benefit of rate reductions of this magnitude resulting from minor technical improvements. A dozen years ago the average domestic consumer used about 50 kilowatt hours per month and paid $2.75 for the current; and, today, the consumption is a little more than twice this amount and the cost is only $3.50. We can visualize the first 50 kilowatt hours as still costing $2.75 and the second 50 costing $0.75. During the past quarter of a century, through technical improvements, the average power-house has changed from a consumption of nearly four pounds of coal per kilowatt hour to less than one pound. This is equivalent to finding a new fuel which yields more than

three times as much electricity as the coal we used in 1923. It would be amazing if we could expect no greater advancement from a fuel giving more than one million times as much energy as coal.

There is, however, another viewpoint which is more hopeful. At the present time the average home pays, let us say, $5.00 per month for 100 kilowatt hours of electric current. This pays for all the components of the services rendered—fuel, generating and distribution expenses, meter reading, bill collecting, administration, interest on investment, amortization, and dividends. If the consumer should double the amount of current used the only cost factor that would be doubled would be the cost of fuel. It costs no more to read a meter, collect a bill, or render the other associated services, for 200 than for 100 kilowatt hours of current. The additional fuel, 25 per cent of total costs, would justify a charge of $1.25 for the additional 100 kilowatt hours or $6.25 for the total of 200. On this basis the cost of 300 kilowatt hours would be $7.50. It will be assumed that the power-house and distribution started with adequate facilities to meet all possible demands of the community.

If a cheap atomic energy source such as lithium is used as a fuel, giving two and a half million times as much current on an equal weight basis, or let us say twenty-five thousand times as much as coal on an equal cost per pound basis, fuel costs become a minor item in the cost of providing electricity and can be ignored. With fuel costs eliminated the first 100 kilowatt hours service to the home could be supplied for $3.75 instead of $5.00 per month. The power company would experience no additional costs if the consumption by the customer were raised to 1,000 kilowatt hours per month, and it could supply this amount of current at the cost of the original 100 kilowatt hours. In other words an unlimited amount of current could be made available to customers for what they now pay for a very limited amount.

It would be found unnecessary to account by metering for the current the customers used. Customers could be given classifi-

cations according to possible consumption and a flat rate fixed for the service. This would eliminate meter reading, customer bookkeeping and billing, and the costs of the power company would be reduced proportionately. Instead of the tentative $3.75 per month for service to a home the cost might be reduced to $2.50. Our communities would be stabilized and the charge could be made on an annual prepayment basis still further simplifying the procedure.

With homes able to use electricity for any purpose desired without giving thought to the limiting factor of cost there would be a tremendous expansion in the use of electricity and in the demand for electrical goods. Homes would be heated and cooled by electricity. Much better homes would result. Unsightly radiators would be eliminated. Walls of the rooms would have built in them semi-conductors of electricity which would provide plenty of heat from an invisible source. There would be built-in refrigeration, vacuum cleaner, and air conditioning systems. Generous amounts of lighting facilities would likewise be built-in. Cooking would be done by electricity.

Industry is a much larger consumer of electricity than homes. In the factories there would be an expansion in the use of current. The increase in the demand for goods would necessitate extension of factory facilities. New electrical processes could be used. Factories would be neater, healthier, and safer places in which to work. Tremendous burdens would be thrown on our industrial system to produce the materials needed for the reconstruction program under which our new national constellation of cities would be created and these could be carried only through the use of unlimited amounts of almost free electricity from atomic energy sources.

Under the reconstruction program there would be increased needs for man power in our production industries. As we reduced our coal requirements the man power in that field would be released and likewise in the oil field, and other forms of economic thrift would become possible.

Tremendous political benefits would result from the use of atomic energy. Political leaders would be relieved of the continual headache of labor troubles in the mining industry caused by miners and operators alike.

The problems in the international situation would be vastly simplified. The Ruhr Valley in Germany has been a continual source of trouble in Europe through the desire of the various nations to obtain access to, and control of, its essential coal supplies which dominate the whole European industrial situation. With atomic energy sources available, coal is not needed as a source of power or of heat. If made available to Europe, reconstruction could be accelerated and its cost greatly reduced. There still remains the use of coal for smelting the iron ore. It is quite probable that electrical processes can be developed which will make the use of coal unnecessary for this purpose. There would thus be eliminated a principal cause of European instability.

Elimination of oil as a fuel source would eliminate a still larger cause of European strife. One of the principal reasons for maintaining Europe in the state of an armed camp, with a continual sounding of alarms, is not only to maintain our control of the oil sources in Arabia and other parts of the Near East but to prevent access to these fuel sources by Russia. With atomic energy sources developed in Russia, in Europe, and in the United States, no one would care a hoot about the oil of Arabia.

Use of atomic energy engines in airplanes and ships making possible flights and cruises of unlimited length without having to visit airports or naval bases for refueling would eliminate the necessity for such establishments and another cause of military irritation would disappear.

The things about which the world is now being kept in a turmoil are the things which will have not a shred of value to us a few years hence if we develop a practical atomic energy source. We are maintaining an atomic bomb project to gain and protect these objectives of vanishing value, and in doing so are

preventing the development of a practical atomic energy project for peaceful purposes that would eliminate our problems. The whole situation seems more than a trifle stupid.

If we would open up the situation in the United States to permit free civilian experimental development of atomic energy sources, not using the bomb materials, perhaps we could permit the continuation of the foregoing impasse without giving it much thought, or support, and let the constructive developments gently ease it out of the national and international situation.

If, however, we went on a new basis of a tenfold increase in the use of electricity, our present power-houses would be hopelessly inadequate to supply the demand. Increasing their capacity means establishing a new national atomic energy electrical system. This will involve the expenditure of a lot of labor and material.

Immediate steps should be taken to plan for this new atomic energy power system which will be the vital force of our national existence. There should be organized without delay an Electrical College or an Energy College. Its membership should be made up of engineering representatives of a wide area of the public utilities industry, river valley representatives, electrical equipment manufacturers, university physicists, sociologists, economists; of representatives of industry, agriculture, the general public, and of the government. It should be organized with a faculty and with a senate, the latter with executive direction. Costs should be met out of federal tax money. The Energy College should be entirely free of federal or other domination. There should be adequate congressional control to assure an inquiry into the operations of the college if such seemed desirable, and an accounting of funds made available. The planning should aim to keep the field under sound democratic operation, open for individual enterprise, steering clear of government or business monopoly.

The problem to be handled is essentially an engineering one

of determining requirements, trends, means of meeting them, and assurance of continued economic operation; so the College would have to be organized primarily as an engineering institution. An organization of this sort would relieve public officials of major burdens which in the past have been unfairly thrust upon them and would require the people to assume responsibilities which they have avoided in the past.

Capitalizing so large a project may require some new procedures but even if such are adopted this should not be used as a peg on which to hang control measures.

PART FIVE

LEARNING HOW

20. ORGANIZING THE ENGINEERS

IF OUR new age is to be engineered, it will throw a tremendous responsibility for leadership on our engineers. It would be well, therefore, to make a survey of the present engineering corps, its status as individuals and as a group, and also of the methods by which we are creating the engineers of tomorrow.

The engineers, in the United States, are a group of 320,000 professional workers engaged in planning, designing, building, operating, maintaining, and expanding the material aspects of the highest order of civilization that exists anywhere in the world. They comprise a group which, through some of its leaders, is conscious of the fact that its responsibilities are not limited to the material aspects of our civilization and that it has social and economic obligations; that the effects of its work cannot be limited geographically and its responsibilities and obligations are likewise world-wide. This approach, however, has been almost entirely neglected in the past in the education of the engineer.

This social consciousness is not a new development. Leaders in both science and engineering have long been aware of the relationship between advancement in these realms and definite trends in the fields of sociology and economics, and the necessity for mutual controls. A quarter of a century ago the American Institute of the City of New York, in awarding its gold medals for significant discoveries, limited its presentation to those whose work was carried on with a consciousness of the "impact of science on society."

When two decades ago, in 1928, the lack of engineered planning and control in our national society led to a critical economic situation, called "the crash," and its second phase, called "the de-

pression," science and technology were accused of causing our troubles. The charge was made that technical progress was being achieved at too rapid a pace and the demand was made that science take a ten-year holiday in order to permit society to catch up with it. Powerful propaganda forces maintained a continuing barrage of publicity which kept the mind of the public focused on the engineers and scientists, thereby warding off discussion of the actual responsibilities that rested in the political and financial realms. The scientists and engineers, however, have been kept completely isolated from all means of exerting any control over the social or economic effects of their work. They have never had a chance to decide how the advances in science and technology would be applied. The injustice of the charge was never made evident to the public.

The situation will, however, correct itself in due time. The scientists and engineers were shouldered, in the minds of the public, with a responsibility and under our democratic way of doing things a man cannot justly be loaded with a responsibility without being accorded liberties and powers equal to the responsibilities. The engineers became very conscious of the necessity for recognizing and accepting their inevitable responsibilities. Engineers, however, are nothing if not practical. They were well aware of the fact that men are not competent to take over responsibilities for social and economic effects of technology without being properly trained and organized, any more than individuals would be competent to undertake the design and construction of a bridge or skyscraper without adequate education, training, and experience.

When and how could engineers be educated and trained to assume social and economic responsibilities for application of scientific knowledge? Who was competent in knowledge and experience to educate and train them? This field of knowledge was a barren desert. There had been a taboo against discussion of the social effects of science and technology.

Just as the various organized engineering disciplines were self-

created it was obvious that organized knowledge in the new field would have to be produced in the same way. This barren, undeveloped field was a buffer state between two separated realms in one of which natural law prevails and in the other man-made law. Interest in cultivating the buffer state would have to be created. Engineers who had been taught that they carried no responsibilities beyond the structures they erected were loath to enter the terra incognito of the buffer state. The more inelastic the mind, the more unwilling it was to adjust itself to new situations.

It was obvious that the new situation would have to be met with new minds, having the courage to enter and develop the new field. There were leaders who knew how to bridge the gap, but these leaders knew that the task was not one which could be accomplished by a few individuals but necessitated a new sense of organization which would permeate the entire engineering corps and that it was necessary, further, to send out emissaries of good will into the older field of economic controls so that an amicable division of responsibilities could be arranged.

Here was an educational task of vast magnitude. The situation was well stated in the address delivered at the 1937 commencement exercises at the Massachusetts Institute of Technology by Gano Dunn, past president of the American Institute of Electrical Engineers and president of the J. G. White Engineering Co., and of Cooper Union, which has a School of Engineering famous for producing outstanding engineers. President Dunn said:

> If the engineer's training neglects the great human mirrors of history and languages, if his mind and heart are not sensible to the great social forces of his day and of his community; if he but feebly develops the subtle qualities of character that make for personality, his career as an engineer is limited, no matter how much science he may know. . . . As the engineering profession has developed, the center of education for engineers has been shifting more toward the humanities. This is one reason for the greater part engineers are playing in the great roles of life. . . .
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> In the field of management, involving the play of the human spirit at its best and at its worst, where, particularly in labor relations,

generosity, loyalty and independence are manifest as well as passion, ignorance, and vanity, the engineers' capacity for organization, leadership and sympathy has rare opportunities. . . .

The social sphere today is still a field that needs the light, a field in which the engineer, with his training and point of view, has open to him the doors of great opportunity. . . . Just as the peculiar equipment of the clergyman, the lawyer, and the physician gives him a peculiar power and authority when disinterestedly devoted to social betterment, so does the equipment of the engineer.

The engineer today finds himself in a pivotal position in industry, intermediate between capital and labor, with the problems of both of which he deals intimately, and is in a position to understand, interpret, and judge. In consequence, there is offered to him, entirely in addition to the service he performs through his engineering function, an opportunity for social service through his professional and personal status which, if he rightly conceives and seizes it, gives him a strategic advantage to render social service which, at this moment, the representatives of the older professions do not possess.

Vannevar Bush, President of the Carnegie Institution of Washington, recent director of the government organization, the Office of Scientific Research and Development, and then Dean of Engineering at Massachusetts Institute of Technology, expressed a similar view in an article "Opportunity for the Professions," in *The Technology Review,* July, 1939. He stated:

We witness today an intensified class of special interests: labor, capital, management, government, farming district and city; skilled artisan and common laborer. The professional man ministers to them all and stands in a group apart. . . . As strife becomes intense, it is well that there should be in society an authoritative group which refuses as a group to join either party and whose members freely take individual positions without prejudice—a group which emphasizes its detachment, whether the strife be between individual groups, or any other groups.

Even earlier than this period, the ferment was at work within the engineering societies. It was set at work less by outside criticism and more by the internal consciousness among the engineers of the larger scope which their activities would embrace because of the inherent nature of their work.

The engineer, like all other professional men—the priest, the lawyer, the scientist, and the doctor—has his prototype in the medicine man, the shaman, of early days. The medicine man, because of his effort in training himself in knowledge of natural forces, was granted a unique position in society in which he was free from many of the limitations imposed on other members and in return assumed obligations of which other members were free. He was required to devote his efforts to the welfare of the members of the community, and the community as a whole. In order to meet this responsibility he was accorded unusual powers and his directives superseded those of the ruler of the community.

As the medicine man developed specialized techniques with the growth of communities it became less practicable to give service to individual members of the community and the medicine men established a liaison arrangement with the rulers under which they ministered to the community as a whole as advisers to the rulers. In this status they became privileged characters. Whereas they formerly derived their strength from their services directly to the individuals in the community they now derived their strength from service to the ruler. The welfare of the ruler became the primary interest of the shaman-priest.

The individual members of the community still required the services of their medicine men for their physical welfare and physicians became numerous in the communities still preserving their extra-legal status since their particular knowledge was not derived through, nor controllable by, kingly directives. The shaman who specialized in astrology, the interpretation of nature and its forces, the progenitor of the scientist, flourished in individual service to the members of the community and frequently incurred the ill will of the ruler by diluting his power, also because they recognized no power of kingly control over the forces of nature. The king as the administrator of the affairs of the people was endowed with unique powers with respect to maintaining the welfare of his state. The shaman who specialized in words of wisdom concerning the relationship of man

to man, found that individual cases contained much in common and formulated these relationships into codes of laws as communities became larger and relationships became more complex. The king, as administrator, announced these laws, usually attributing their origin to the gods, thus giving even the king an extra-legal status. There was just one "law" in each community, the king's law, and the priest-lawyer was very much the protégé of the king—and still is. Even today the lawyer has never been freed from being an officer of the court, or, in other words, the servant of the king. The law, from the viewpoint of the individual member of the community, has never been written. That in use today, even in such an advanced democracy as the United States, is very definitely and dominantly "king" law. The professional status of the lawyer is derived from the power of the king and has not attained the extra-legal status of the other professions.

The status of the medicine man, or shaman, who propitiated and invoked the gods has been a peculiar one. He was the original first scientist, engineer, and priest. In the early days, every family had its household gods and gods of the field and of the woods, which were invoked for guidance and protection, but when their aid failed the fault was believed to lie in the individual who then sought the aid of the shaman who had a greater understanding of the ways of the gods. As communities developed, the king, with his greater responsibilities, had the greater need of the services of the shaman-priest who could interpret what the gods intended for the welfare of the members of the community and which the king could hand down as laws, or who could, in individual cases, direct the king to act otherwise than as specified in the codes. It was embarrassing to have individuals in the community consult their individual gods of the hearth and of the fields for individual guidance which might differ with that coming from the king, and both could claim the same extra-legal status. Suppression of the individual household gods was in order, accompanied by elevation of the national god. Chris-

tianity, in its broadest sense, is a revolt against the king's god as the Christian doctrine re-established contact and orthodox relationships between man and his universal God. The "priest" (used in the generic sense) has not yet achieved full divorce from the "king." The professional status of the priest is essentially and completely extra-legal, that is, has its authority beyond human organizations of any kind.

Out of the studies of nature by the early astrologers has developed a host of modern scientific disciplines and a vast array of knowledge of the forces of nature and how to control them. The application of this knowledge to human needs is the basis of engineering.

The engineer, since the earliest days, has been the protégé of the king. Just as in the early days, every family had its individual household gods so was every man his own engineer. It has always been the fundamental and inescapable responsibility of every individual to acquire and possess knowledge and to apply this knowledge for his own welfare. This responsibility could not be renounced nor shifted to others. The greater the amount of knowledge the individual acquired, and the more efficient its application, the greater was the welfare of the individual and the higher his standard of living.

In projects involving the community as a whole, the tasks were of such magnitude that they could not be handled by single individuals and the king had power to call on all citizens to aid. Sometimes in order to accomplish a task at all, even with great numbers of workers, the greatest efficiency in the use of man power and materials was required. Directing such projects became the task of individuals who possessed a peculiar flair for handling not only materials but men in the most economical manner. These were the engineers (still called priests in the early days) and they were very valuable members of the king's staff. They were required to direct their efforts to increase the power of the king for either protection or aggression.

It was necessary, quite frequently in the early days, for the

engineers to protect the king against the people. Since the king assumed divine prerogatives, as intermediary of the gods, and the gods held the final power and responsibility for the welfare of the people, the people held the king responsible for such matters as bountiful harvests and prolific herds of cattle. It became necessary, therefore, for the king to propitiate the gods in such practical ways as the building of irrigation systems which would provide the bountiful harvests and increasing herds so that the people would be happy and prosperous, but primarily be able to pay generous taxes to the king.

All engineering was essentially military engineering up to about two hundred years ago and all engineers were employed by governments. The term civil engineer originated in England and both a builder of lighthouses and a builder of steam engines described themselves as civil engineers. The highly nationalistic nature of military engineering prevented the wide diffusion of knowledge of the engineering arts and seriously handicapped the development of this field. This situation operated to slow down the tempo of civilization.

Science has always been universal and has always maintained its international status. It was permitted to do so because its findings seemed so far removed from practical affairs. It was very democratic and totally unorganized and consisted largely of the work of individuals who studied the stars, dug bones out of the ground, collected minerals, and classified plants and animals. This work seemed very much safer than that of the alchemists, which threatened to undermine civilization by finding a way to transmute base metals into gold. The alchemists were dangerous, and the welfare of the state required that they be suppressed. That elixer of life stuff, too, if they achieved it, would place too much power in their hands. This was the reason why the alchemists, who in every sense were scientists, were isolated from the other scientists so they could be ostracized and kept under official taboos. Their suppression delayed progress many centuries.

During the period in which science was developing at a

tremendous rate, the kings were so interested in building empires through wars and exploration that the statesmen paid little attention to its growth and failed to grasp its significance. The colleges and universities, originally and primarily institutions for training candidates for priesthood and for membership in religious orders, showed greater wisdom. They provided academic homes for those who were interested in advancing the study and control of nature. They gave a home to, and sought to adopt, science. Science, however, remains an entirely independent entity and cannot be absorbed within any other entity.

The support and patronage of the university has permitted science to prosper as no other human institution has ever flourished. As science flourished it created an avalanche of new knowledge, the application of which to human wants and needs laid an ever expanding foundation on which engineers could build their structures.

Just as science was given an academic home by the universities, so was engineering. At first independent schools were established, the National School of Roads and Bridges, in France, in 1747, and the London Mechanics Institute, in England, in 1823. In the United States the Rensselaer Institute was established in 1824. At Yale, in 1847, the Sheffield Scientific School was established and at Harvard, in the same year, the Lawrence Scientific School came into existence. Emphasis was then on the practical applications of science and these institutions were more engineering than scientific schools. The Massachusetts Institute of Technology was established in 1861 and the Stevens Institute of Technology in 1870. Since that time the universities have created engineering schools in great numbers.

Vannevar Bush, in speaking at the centennial celebration of the Lawrence Scientific School (1947), concluded his historical sketch with the statement:

> This is the emergence, development, and progress toward independent stature and recognition of engineers as a distinct group or entity—a profession—among our people.

THREE-QUARTERS of a century ago there were two engineering societies, one for civil and the other for the mining engineers. The number of engineering societies in existence today is not known but it is large as practitioners of more and more highly specialized arts become organized into small but growing groups which use "engineering" in their society names.

The various engineering societies had very little in common so far as their activities and plans are concerned until Andrew Carnegie, who had made a large fortune in the steel industry, gave, in 1904, a substantial gift and endowment to an organization, United Engineering Trustees, Inc., formed for that purpose by the four major engineering societies. These societies, with the years of their organization, are: The American Society of Civil Engineers, 1852; American Institute of Mining and Metallurgical Engineers, 1871; American Society of Mechanical Engineers, 1880; and the American Institute of Electrical Engineers, 1884. These are known as the Founder Societies. Carnegie's gift provided them with a beautiful building at 33 West 39th Street, New York City, and, backing it in West 40th Street, the Engineers' Club.

Through this gift Carnegie catalyzed the engineers into full evolution leading to the realization of their professional status and co-operative activities.

In 1907 the United Engineering Trustees established the Engineering Societies Library in the Engineering Societies Building. The four Societies merged their collections. It now has a quarter of a million books catalogued on nearly three-quarters of a million index cards. Its users are scattered all over the world. The library renders a unique research service, which makes it possible for engineers in all parts of the world to use its facilities by mail. Nearly 25 per cent of its one hundred thousand consultants use the mail service. It renders an engineering aid service to all libraries in the United States.

The Engineering Foundation was organized in 1914 to aid the support, organization, and co-ordination of selected re-

searches in engineering and related sciences, including economics and the human aspects of engineering.

The American Standards Association was organized in 1918 to provide a means for industries, technical organizations, and governmental departments to work together in developing acceptable national industrial standards and to prevent overstandardization. The American Standards Association has functioned with outstanding success as a democratic institution which sets up a framework in which any group of industries can get together to work out standardization problems. All participation is entirely voluntary. Through this process industry has been provided with the machinery for adjudicating its own problems and making any intervention by government superfluous.

The Division of Engineering and Industrial Reasearch was organized in 1919 as one of the seven divisions of Science and Technology of the National Research Council. The division included, in addition to the Founder Societies, American Society of Refrigerating Engineers, American Society for Testing Materials, American Society for Metals, American Society of Heating and Ventilating Engineers, Illuminating Engineering Society, Western Society of Engineers, Society of Automotive Engineers, and the American Welding Society. The purpose of the Division is to encourage, initiate, organize, and co-ordinate fundamental and engineering research in the field of industry and to serve as a clearing house for research information of service to industry.

An Engineering Societies Employment Service was organized in 1919, with offices in New York, Chicago, and San Francisco, as a placement service for members and to aid employers seeking engineers and engineering societies.

American Engineering Council was formed in 1920. It comprised seven national societies, four independent state societies, and fourteen local societies. It was formed as a central agency to further the public welfare wherever technical and engineering knowledge and experience are involved, and to consider and

act on all matters of common concern to the engineering and allied technical professions. It was created as a service unit to provide a clearing house for information, a forum for deliberation, and as a means of giving national expression to the aims of the engineering profession as a whole, dealing with relations of engineers to the public and to governments in matters of engineering content.

Engineers' Council for Professional Development started its very successful career in 1932. It was formed by the joint action of the four Founder Societies, the National Council of State Boards of Engineering Examiners, the American Institute of Chemical Engineers, organized in 1907, and the Society for Promotion of Engineering Education, organized in 1893 by the engineering educators. It is a conference of engineering bodies organized to enhance the professional status of the engineer through the co-operative support of those national organizations directly representing the professional, technical, educational, and legislative phases of an engineer's life. Its program includes: vocational orientation of prospective engineering students; formulation of criteria for colleges of engineering; plans for further professional development of engineering graduates and of non-graduates; and, devising methods whereby engineers attaining suitable standards may receive corresponding recognition.

The memberships of the various national societies associated in the Engineering Council for Professional Development are: American Society of Civil Engineers, 23,000; American Institute of Mining and Metallurgical Engineers, 15,000; American Society of Mechanical Engineers, 23,000; American Institute of Electrical Engineers, 27,000; American Institute of Chemical Engineers, 9,000; American Society for Engineering Education, 5,000; Engineering Institute of Canada, 7,000.

Engineering, as an unorganized practice, is as old as man but as a free, organized profession, it is very young. Some pessimists in their darker moments have surveyed the fledgling and asked:

"What is engineering?" and "Is engineering a profession?" Many definitions of engineering have been written. The one which carries official sanction, to the extent that it has been formulated by the Engineering Council for Professional Development and published in *Engineering as a Career* is:

> Engineering is the combination of art and science by which materials and power are made useful to mankind.

THE ONE, beyond this, which seems to have received least criticism and most acceptance within the ranks of the engineers is that written by Gano Dunn:

> Engineering is the art of the economic application of science to social purposes.

IT WILL be noted that in them, and in practically all other definitions, engineering is defined as an art. It is rare for an engineer to be required to solve the same problem twice. He is always encountering new situations, or, from a similar situation, is called upon to produce new results. Not only is the engineer called upon to solve problems which have not yielded to routine solutions, but he is required to produce results at minimum cost, in minimum time, with a minimum use of materials and man power. An engineer has been described as a man who can accomplish with one dollar results for which others would require two. A definition which also tells a story is: The engineer mobilizes methods, materials, mechanisms, money, and men to produce maximum results at minimum cost.

The developing social consciousness of the engineer is well described in a credo recently adopted by the Engineering Council for Professional Development. Those who are initiated into the medical profession are required to subscribe to the Hippocratic oath which makes the physician a trustee for the knowledge of the healing art which has been revealed to him, requiring that he use it only for human welfare and refuse none who requires his aid. This oath is supposed to have had its origin in the writings of Hippocrates, the Greek physician, who flourished

about twenty-five hundred years ago. The engineers have not heretofore developed such a basis for an ethical code. The credo adopted by the Engineering Council for Professional Development may, in the course of time, pass through polishings and perfections, as was the experience of the Hippocratic oath. As it stands, however, it is a well-engineered statement which might well become the basis for a ritual of initiation when the neophyte is admitted to the ranks of the masters. The credo is:

FAITH OF THE ENGINEER

I AM AN ENGINEER.

In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests of and the good name of any engineer that I know to be deserving; but I will not shrink, should my duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and, especially, to the instruction of younger members of my profession in all of its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

The next step in the organizational progress of the engineers is the creation of a single engineering society of which all engineers can become members and which, through the greater power that would come from a unity of purpose and action, would make it possible to raise the professional status of the engineer and give him a greater power in the national community. Discussions are under way within the major societies and in the technical journals. The basis of unity is within sight as the difficulties involved are not of a fundamental nature.

The foregoing gives a picture of a highly organized corps of professionally trained men competent to tackle the most gigantic tasks which society can impose on them. As a matter of fact, they will impose the tasks on themselves for no other group is competent to assess situations and propose programs or remedies in all matters that concern controlling our environment or providing the mechanisms of civilization. They are, however, thoroughly grounded in the art of co-operating with other groups which carry executive and administrative responsibilities.

There are other groups who, in essence, are engineers but carry other titles. Our medical doctors, for example, are, in their activities, health engineers. Theirs, too, is an art in which the knowledge of science, physical and biological, is applied to individual human welfare. In this field there has taken place a broadening of the base of operations so that knowledge of hygienic matters is applied on a community basis, to establish preventive measures in the battle against disease, to tackle diseases on a national scale as when an infectious disease becomes virulent and highly contagious, or to carry on educational programs directed at eventually making the great body of citizens a mighty army that can fight to protect its own health interests.

Direct linkages exist between the work of the health engineers and construction engineers. The civil engineer designs and builds water supply and sewage disposal plants for our cities. Both, however, are based on biological knowledge but oppositely applied in each case. In building water supply systems, provision

is made for taking advantage of the biological knowledge to keep the water supply free of bacteria, while in building sewage disposal plants advantage is taken of biological knowledge to put bacteria to work to consume all solids in the water, or to precipitate the solids in such form that they can be returned to the soil as fertilizing material. Knowledge supplied by the medical engineers is the controlling factor in the design of buildings and is applied so that the buildings when constructed will provide the most satisfactory conditions for the health and comfort of the occupants. The knowledge of the biologists is used in designing industrial plants so that health hazards, and dangers to workers, may be eliminated, and by-products do not become a community nuisance.

Psychological and aesthetic factors have been injected into the engineering field by the biologists and health engineers. Use of sound, light, color, and rhythm has been found effective by engineers in design of plants to bring about more comfort and higher morale among workers with resulting higher efficiency and increased output.

The health engineers are likewise very conscious of the social and economic implications of their work. Occasionally a courageous genius comes to light among them as the doctor who gave his patient a prescription written, not in Latin but in plain English, and which was to be filled, not by the druggist but by the patient's employer. The prescription the doctor wrote was:

Pay this man decent wages.

THE HEALTH engineers, numbering about two hundred fifty thousand, are organized in one large and two smaller national societies and many groups of specialists. The former is the American Medical Association, with headquarters in Chicago, which is composed of all the state medical societies which in turn are composed of all the county medical societies in each state, and these societies are composed of the individual doctors as

members. The other two societies are the American College of Physicians and the American College of Surgeons. In addition there are many societies made up of highly specialized groups of doctors. Then come the borderline societies of which both physicians and scientists are members. These operate in such fields as endocrinology, nutrition, biochemistry, anthropology, physiology, bacteriology, immunology, radiology.

High pressure was brought to bear on the medical profession in the immediate pre-war era to bring about government control in the form of socialized medicine. There are vocal groups which have held this development as their goal for a long period of time in the sincere, but mistaken, belief that a group of men organized with a government title could have access to some magic which would not be available to the same group under democratic auspices. Before the war, the political powers used this movement as a club over the medical profession with an "either—or" ultimatum attached to it, to whip it into line so that it would, without resistance, meet the demands of the military machine for such medical co-operation as it ordered. The technique was successful and the pressure for socializing medicine has dropped down to one atmosphere.

The same technique was used by the political groups to whip business into line with its war plans. Suits were brought against the biggest and most loyal business companies charging foreign entanglements (which, in some cases, the government had sponsored for them in previous years). Our businessmen are, in the broadest sense, production, distribution, and service engineers, despite the fact that there is only a nebulous educational discipline available for training them, and they have not advanced to professional status, nor risen to a code-of-ethics basis of operation.

We are, in a sense, all engineers in that we apply more or less scientific knowledge to the problems we encounter in the art of living our individual, family, and community lives. In the vast majority of cases we fail to bring adequate knowledge and

training to our activities to entitle us to the status of professionals in the art of living. This is not always the fault of the individual because, very frequently, as in critical situations affecting our national life, we not only lack, but are intentionally deprived of, essential information which would clarify our thinking and are supplied instead with misleading propaganda designed to throw us off our rational basis of thinking.

Just as our designing and construction engineers, and our health engineers, are highly organized on a professional and ethical basis to operate for human welfare, so is it desirable for the entire national community, in all of its members and activities, to be similarly trained and organized so that all may, at all times, with adequate knowledge and understanding of problems, co-operate with each other on a democratic basis to solve our problems, and project and consummate tremendous programs for the advancement of the human race. The task is not a small one, nor an easy one, but it can be engineered and started immediately.

21. WHERE IS THE MULTIMAN?

WHAT DOES an engineer look like? The movie fan and consumer of fiction can describe him with perfect precision—he wears heavy, high-laced boots, riding breeches, a leather jacket, a sombrero, and carries a roll of blueprints under his arm, has a slide rule sticking out of his pocket, is tall, well built, lithe, and handsome, has worked on all continents and in every clime from equator to the poles.

Some day, somewhere, someone may find such an engineer. So close to Hollywood as Signal Hill oil field, which is almost in the backyard of the studios, you can search in the forest of derricks or off in the toolrooms and find men who look like truck drivers, butchers, certified public accountants, lumbermen, school teachers, farmers, miners, senators, and corporation vice-presidents, and there is no way of telling which is the engineer until you start talking to them.

Nor would the situation be very different if one dropped into the headquarters of an engineering organization. A drafting room would give a clue, but in other departments, if one ignored the pictures on the walls and the titles of the volumes in the bookcases, the rooms might be mistaken for the offices of a foreign trading concern, an advertising agency, travel bureau, or a stockbroker.

There are few outward distinguishing marks of an engineer; he can be found draped over a drill in a mine gallery among a group of miners examining a newly exposed rock face and you "can't tell t'other from which," or you may find him sitting in a group around a long mahogany table at a meeting of the board of directors of a giant corporation and it is difficult to tell who

is the bank president, who is the engineer, and who the vice-president in charge of sales, so far as appearances are concerned.

When the man who is heart and soul an engineer opens his mouth, however, the difference becomes apparent; the precise, carefully-weighed conversation of the engineer stands out in strong contrast with the garrulous gabble of the extreme type of bulldozing business executive. The engineer can do a very efficient job of bulldozing, too, but as a rule he rarely finds it necessary to do a lot of table thumping and to use a thunder-tongue to gain his point.

The engineer can also be found wearing white tie and tails and when so accoutered can be seen exhibiting more poise than a college president, appearing more dapper than a diplomat and more magnificent than a Russian ambassador. The engineer can, and has been, seen in these aspects, but he can also be viewed in others in which he is more likely to be seen slipping away to the bar and getting himself a cup of Durango snake oil, and finding out from Bill Simpkins what deflections were observed in the weight tests on the floor of the new type of reinforced concrete building he recently completed.

There isn't much small talk in an engineer; as a rule his lingo is languid, and he is very cautious with his chatter. But this is not universally true. Examples of the other extreme can be found, fellows who get hipped on some subject and become chronic ear benders, gushing like the nozzle at a placer mine, exhibiting usually an inferiority complex as a manifestation of their frustration in failing to have some pet plan accepted.

The engineer is John Q. American, high type. It is difficult to make a more specific statement and have it apply to all engineers. They are everything other men are. There isn't an engineer-type. We haven't developed a professional type in any field, although if we group all of the professions it is probable that an archetype could be established that would differ from the archetype of a non-professional group. The engineers are a cross

section of what, under present standards, we call the upper quartile of the population. In the past there have been practically no selective processes applied to those who wished to take training for engineering. A recent survey revealed that four out of ten chose engineering because it seemed to offer a life of romantic adventure, or because parents made the selection. Some, probably, were impressed by such doggerel as—

A rambling wreck
From Georgia Tech
And a helluva engineer . . .

and

The engineers
Have hairy ears,
And zippers on their breeches,
They break hard rocks
With iron stocks
And sleep in dirty ditches.

There is many an engineer, however, who is always meticulously groomed, who never handles anything more closely resembling a drill than a pencil, and whose closest approach to handling machinery is turning a pencil sharpener.

Nearly 320,000 engineers now hold licenses from state examining boards. About one out of three, less than 100,000, are members of the four Founder societies, the Civil, Mining, Mechanical, and Electrical, but it is probable that the great majority of those holding licenses are members of some specialized engineering society, of which large numbers have sprung up in the last decade or two.

A revealing survey of the engineering profession was recently completed by the Engineers' Joint Committee representing the four Founder Societies and the American Institute of Chemical Engineers. The results were assembled into a comprehensive report by Andrew Fraser, consultant, of Washington, and published by the Council. It is titled "The Engineering Profession

in Transition" and will yield a big return for the dollar invested. The following is but a small sample of the great fund of data it contains.

Four out of five practicing engineers are college graduates. The great bulk of the engineers, 60 per cent, hold bachelor degrees. This group is balanced on one side by about 15 per cent who failed to complete their college training and 5 per cent who received no college training, and on the other side by 15 per cent who hold master and 5 per cent who hold doctor degrees.

Governments, from federal to municipal, employ 20 per cent of all engineers; 66 per cent of all engineers are engaged as employees; 12 per cent are engaged as consultants or are operating their own business, and a small per cent are in other capacities.

During his first three years after graduation, the engineer will average about $250 per month salary; by his fifth year, $300; in his tenth year, $400; his fifteenth year, $500; and, by his thirtieth year, $600, after which there is slight change, when the data for the five principal branches of engineering are averaged.*

Earnings increase more rapidly in chemical engineering, with less rapid increases, in order, in mining-metallurgical, specialized engineering, mechanical, electrical, and civil. Work for governments, federal to municipal, pays less than that for private industry. The pay is about the same immediately after graduation but for men with thirty years' experience, government work averages about $500, and private industry about $600 per month.

There is a narrow range of difference in individual earnings in an engineer's first year; the upper 10 per cent earn $4,000, and the lowest 10 per cent earn $2,250 a year. Thirty years later there is a wide spread of difference; then the upper 10 per cent earn $19,000 and the lowest 10 per cent earn $4,000 a year, Fraser's report shows.

* These figures do not apply to current conditions in the rising inflationary spiral.

The largest group of engineers, 30 per cent of the total, is engaged in administration-management jobs of a technical nature. The next largest group, 15 per cent, is engaged in design; development occupies 7 per cent, applied research 6 per cent, and supervision of construction, consulting (as employee) and teaching each somewhat less than 5 per cent.

Civil, electrical, and mechanical engineering employ 75 per cent of all engineers, the numbers being about equally divided among them. Chemical engineering accounts for 10 per cent and the remaining 15 per cent is widely dispersed.

A very definite shortage of engineers exists at the present time. In the pre-war period about 12,000 graduate engineers were produced in each year. The war situation not only took a great many engineers from constructive work to war activities but took the vast majority of engineering students for the armed services, in addition to larger numbers who, during the war period, would otherwise have advanced to entrance into engineering schools. Some students received a speeded-up training with which they will be handicapped for the remainder of their lives.

The war-caused shortage is probably in excess of 40,000 graduate engineers. The number of students in training will yield approximately 15,000 graduates a year. The G.I. Educational Program made it possible for many who would not otherwise be able to do so, for financial reasons, to take engineering courses. In spite of the government financial aid to its ex-soldiers and ex-sailors, the engineering schools were prepared to accept more students than they were receiving. Talks with executives of engineering schools indicated that they were well pleased with the student material they received, that the student body as a whole was of higher caliber than in pre-war years, but that a very large percentage of the applicants for admission could not be accepted because of deficiencies in personality or aptitude. The raw material for making engineers is not too plentiful.

The increase from 12,000 graduates per year, pre-war, to

15,000 per year, post-war, is less than the normal increase that would have been expected from the normal increase in our productive activities regardless of war intervention so that we are now on a sub-normal schedule in the production of engineers with a deficiency being created each year to be added to the 40,000 war period deficiency. Ten to twenty years may elapse before we return to pre-war standards in training engineers.

If we integrate all situations as of 1946, we find that the engineer is earning $5,500 a year and that it took him fifteen years to reach this status. This is approximately $115 per week, and represents about a $1,000 a year improvement over the 1939 situation when it was found that it took nearly twenty years to reach the $100 per week salary.

These earning levels are excessively low. There has been much discussion in engineering journals about the inadequacy of the earnings of engineers. About the only suggestion offered for improvement was to limit the production of engineers and let the law of supply and demand operate. The demand for American engineers in all parts of the world continues, but the supply of those who are willing to take the jobs offered is very small. A substantial increase in the salaries offered might help balance the situation, but almost no effort is made to take advantage of this solution. This picture describes the domestic situation equally well.

Post-graduate education has a definite financial value. From the data of the earnings of engineers with the various levels of education, it can be estimated that the doctor's degree is worth an additional $63,000 in a thirty-five-year working period when the earnings of the Ph.D. are compared to the earnings of the man without college training. The difference in earnings for this period average about $1,800 a year. If seven years' earnings, which might have been gained while the Ph.D. was in college, credited at the non-college rate, are charged against the foregoing value there remains a net value of $38,000, or about $5,500 for each year in college. Forty years beyond college age, the man

without college training earns an average of $6,000 a year, and the Ph.D., $7,700. Beyond the purely financial aspects of this situation is the larger viewpoint that the more adequately a man is supplied with organized knowledge the greater are the opportunities that come to him for rendering service. There is, however, a purely artificial value that is placed upon evidence that a man has gone through the motions of acquiring an adequate education, but, as a rule, erroneous judgments of men based on such unsound formulas are corrected as time passes all individuals through merciless tests of actual abilities.

The atomic energy era which will necessitate a vast expansion program may burst upon us with dramatic suddenness with an accompanying demand for great numbers of scientists, engineers, and technicians. They will be wanted for immediate services, but it takes at least four years to receive training in an engineering school. Another three to five years are spent as a student and draftsman in an engineering organization and another equal period in gaining experience that is necessary before the individual can take over designing and construction responsibilities. At least ten years are required, therefore, to train a man before he can undertake full-fledged engineering activities. At least twenty years' experience is considered necessary before an engineer has enough background to set up an independent consulting practice.

If the United States is to be in a position to pass through an expansion phase during the next ten years it is likely to find itself short of the men competent to motivate it. Maintaining earnings of the great bulk of the profession (66 per cent of all engineers work for others) at levels inconsistent with the dignity of the profession is not likely to attract increasing numbers of desirable types into this field and may leave the country dangerously undersupplied with essential talent.

Earnings, however, are very much of an individual matter. In the report of the Engineers Joint Council, the top earnings reported were slightly above $19,000 a year. There is, however,

this important fact to keep in mind—the top 10 per cent refrained from reporting their earnings.

Earnings in excess of $19,200 are achieved by about 4 per cent of the engineers and earnings in excess of $5,000 by about 40 per cent. Many engineers work themselves into administrative posts where their services are of a non-technical nature; they become business executives and achieve earnings much higher than those who are engaged in technical activities, yet they retain their standing as engineers.

A good engineer, who is not a good salesman in selling himself and his accomplishments, will stay in the lower salary brackets and his achievements will lack recognition. This is not only a loss to the engineer but a loss to the organization by which he is employed, for the advancement represented by his researches or developments do not become incorporated into its business and it has less to sell. A good salesman who has accomplished an engineering development with a value of ten points is likely to have little difficulty in selling his executive, whereas a good engineer with a development worthy of a rating of one hundred points, but who is a poor salesman, may be entirely unsuccessful in putting his idea across to the executive.

Almost every type of individual is found in the engineering profession from the loquacious back-slapper to the solitary researcher and there is a use for all of them. Engineering is engaged in applying scientific developments and the application is usually made at the behest of commercial and government organizations. Commerce and science are fields which have little in common. They talk completely different languages. The ideals of science and the goals of business cannot be juxtaposed in any way. The scientist and the businessman live in different worlds. Engineering bridges the gap between these two realms. It must talk the language of the businessman and the scientist; it must have an understanding of the ideals of the scientist and respect for the purposes of the businessman and the methods of the politician. It is a rare individual who possesses all the qualifications neces-

sary to make harmonious and effective contacts with all of these contrasting fields.

If all of the 300,000 engineers could be examined as to their personalities and aptitudes, comprising scores of factors, it would be found that each factor, when charted, would give what the scientist calls a Maxwell distribution curve. If the attitude toward people were measured, they would be found to range from the extreme extrovert to the extreme introvert. The extremes in either direction would be found few in number, with the great majority clustering near the median position.

The extreme extrovert doesn't bother much with learning anything; he has learned that he does not have to know anything if he knows the right people who know things. He is always gadding about making contacts, trying to find out "what's cooking." He is always on the inside track of something. He despises anyone who is not an American and understands perfectly why Mephistopheles is shown in a red suit. He thinks technicians are a dime a dozen but when he is selling a bill of goods "his engineers" are the greatest gang of geniuses that ever slipped a slide rule and can transform plans into plants before other fellows know a contract has been signed. To him, the end justifies the means and whatever procedure works out to his advantage is a principle of universal good. He is long on promises and looks to the other fellow for performance. He is not even slightly abashed if he is found pursuing entirely contradictory courses. He believes wit is more potent than wisdom and is willing to build his strength on the other man's weakness, if necessary. Aggression is the mark of a courageous gentlemen when he uses it, but the device of a disreputable devil when the other fellow manifests it. He knows lots of clever lawyers who can interpret any code of ethics to prove that what he did was on the "up and up." What he decides is right—is right because he controls the money. He would sell anything for any purpose; his responsibility ceases when he delivers the goods. The extreme extrovert is

a spectacular individual; he clears a path of progress like a forest fire.

The extreme introvert, at the opposite end of the scale, does not bother cultivating people; he is quite self-sufficient. He, and perhaps he alone, is aware of his own gigantic stature in the intellectual field and finds few who can attain his altitude and populate a productive friendship. His self-assurance concerning the unlimited extent of his knowledge gives him a sense of independence and he looks upon the gregarious extroverts as a bunch of cringing cowards who are afraid to stand alone and must mobilize for moral support. He pities people less productive in ideas than himself. He respects principles and despises practical procedures. He is more interested in production than profit; more interested in creative effort than in costs; more interested in philosophy than politics. He can't compromise; the other fellow can't be even partly right and in disagreement with him. Alternative courses are a sign of intellectual weakness and to him "factors of safety" are "factors of ignorance." He has a minimum of faith in his fellowmen and unlimited faith in his own infallibility.

If we could take Mother Nature's mixing bowl and dump into it such an extreme extrovert and such an extreme introvert, merge the two until a state of equilibrium is attained, roll out the mass and take the cookie cutter and stamp out the shape of two men, each of them would be a much closer approach to the ideal engineer. Perhaps civilization could survive the operations of 300,000 ideal engineers. They might produce an ideal civilization and then we would be face to face with the rather sizable task of operating an ideal civilization with a human race that still lacks a few more points of progress necessary to reach the ideal state of human perfection. Perhaps we might get along without the ideal engineers and by properly administering our extreme extroverts and our extreme introverts we might be able to get the self-sufficient extreme introvert to design the ideal

civilization and the gregarious extreme extrovert to sell it to the human race, and after they have paid for it, the chances are they will learn how to run it. They cannot do any worse than has been done in the past.

The engineer must face the test of learning how to achieve equilibrium among human factors as well as among physical forces. The metallurgical engineer may be an expert with his phase diagram for the production of clean steel but he should also know something about the "silver lining" and the "golden rule." The chemical engineer may be well informed about the degrees of freedom in his chemical solutions but he is not a well-rounded individual unless he knows something about the efforts of the human race to achieve a degree of freedom. The chemical engineer spends his life producing controlled environments in which molecules may do their best work for a particular purpose but no one seems very much interested in producing controlled environments in which particularly useful human beings can perform their best work for social advancement.

The electrical engineer is not reaching his farthest horizons unless he gives thought to analogies between the techniques of his art and the problems in the fields of the humanities. He will have to recognize the equivalent of the heat producing, workless, wattless current among peoples which is causing destructive loss when the potentials of progress in an economic circuit get out of phase with the current of human needs, and will have to propose the techniques by which inductors or capacitors can be added to the circuit to eliminate the phase lag or lead and bring a unity power factor to the human race. This is the engineering approach as contrasted with the techniques of our extreme extroverts in the political field whose only corrective process is to smash the machine that gets out of phase.

Engineers have been indoctrinated for so long a time with the story that their responsibilities end when they have made a machine, completed a plant, or erected a structure, that it will require a major readjustment to shift over to the new view-

point, which is that they have a responsibility for the effects produced by their constructions and will have to include in their plans means for carrying such responsibilities.

Engineers in the future will have to be bigger men than they have been in the past. The demand will exist for men exhibiting greater aggregations of knowledge and wisdom than can be found in a single individual anywhere within the human race, yet the demand cannot, with safety, remain unsatisfied. Perhaps the only solution will be the creation of a substitute in the form of the multiman. As a matter of fact, the demand has long existed for multimen and we have been trying to handle our problems through minimen.

The creation of the multiman will be a feat of organization. It will not be too easy or too difficult a task. It is a task in the field of human engineering. It calls for a blueprint of purpose and a structure composed of human talent. It is a case of doing with the individual man what nature did with the single cell organism—organize a number of them into a co-operative individual.

The multiman is a group of individuals intimately related in the primary purpose of advancing human welfare, each individual contributing a specialized knowledge and all such contributions concatenated into a functioning organic synthesis whose conation will function as the mind of the multiman.

A multiman would differ from a committee. The latter group is rarely free from selfish interests of its members. A multiman's purpose is definitely established and is in excess of that which can be achieved by one or all of its members working outside an organically established relationship.

Every president of an organization, every dean of a college strives for a board of directors, or a faculty, that will function as a multiman. It will be necessary, however, for individuals to be willing to manifest a higher order of dedication to purpose and altruistic idealism than are usually found in such situations, in order to make the multiman idea a success. Some university

laboratory research teams closely approach this ideal situation. We will have to learn how to match men with greater precision and success than a jeweler matching pearls in a necklace in order to achieve a multiman.

The super-engineer of the future may have to be such a multiman, a many-sided group covering all the physical and social sciences, which will bring all of its combined knowledge to the solution of all aspects of engineering projects, including the social and economic effects of technology.

22. TOMORROW'S BRAINS

KNOWLEDGE not built into a sound philosophy of life is the most devastating factor in our modern civilization. Our entire educational system is dedicated to the purpose of imparting information not well co-ordinated or systematized and completely and intentionally divorced from its larger philosophical implications. The larger pattern of cosmic relationships is not only ignored, but rejected, and placed under a taboo.

Because of this situation we are producing year after year crops of intellectually-dwarfed and midget-minded graduates whose limitations make them easy victims for compliance with a continuation of the system. Many, fortunately, overcome their deficiency states and gain the larger picture of man and his relation to the cosmos, but since they deviate from the standard of the herd they are, more often than not, treated as mavericks and aberrants of a dangerous type.

There is no novelty in educational circles to the basic truth that education is, fundamentally, a process of drawing knowledge out of its hidden recesses in the totality of the individual, but the actual practice of pedagogy is to pour in bald, naked, machine-cut facts, sterile of any vital valence bonds which would enable them to link themselves into larger patterns that would reveal greater truths.

The professor who pours canned units of knowledge into the minds of students is just a shopkeeper who starts business with a stock of facts which he is able to sell each year to a new class of students without diminishing his stock, and usually without ever making additions to it. There is, of course, a very definite value of practicability to such a procedure since it imposes minimum

demands upon teacher and student and makes possible the mass production of informationalized groups. All that is required of the student is a certain amount of cerebral storage space, or, if lacking this, a set of notebooks or handbooks. The treasonable thought that there may exist a source of knowledge beyond the professor must never be suggested, and it would be open rebellion to tell the student that he could do some thinking for himself and could possibly make a contribution to knowledge. Conversely, any questions on the part of the student indicating doubt about the complete and final validity of the statements communicated to him is clear cut evidence of a subversive type of mind.

It is doubtful if there exists an individual with a normal mind who cannot be educated more successfully than he can be informationalized. Every such person presents some facet of his personality which can be catalyzed to produce thinking processes linked to the cosmos and tapping the infinite source of knowledge. Thereafter the student requires but a minimum amount of guidance and becomes a focus for self-informationalizing activities and that which is acquired does not go into dead storage but finds its place on an expanding frame of reference where facts become self co-ordinating, revealing truths greater than the facts which contribute to them.

The reason for the latter process of education being neglected and the former process of informationalizing being preferred is that the process of education makes the student largely independent of the teacher and establishes nature as the ultimate authority for knowledge. Nature is not like a practical man; it is so unyielding, so unwilling to compromise, so adamant against making treaties. Acceptance of nature—and the inevitable consequence that the universe is a cosmos ruled by ultimate order which links the smallest atom to the most distant star and includes man and his relationships in its fundamental harmonies, and that this cosmos contains the ultimate source of truth, the infinite source of knowledge, and the final authority—places a limitation on man-made authority. The informationalizing

process makes the college the final authority, and boards of trustees and boards of regents—products of the informationalizing system—are usually practical men who recognize the utility of making suitable arrangements to meet existing and ever changing situations. Pressure of circumstances usually forces them to remain practical even when they have attained the larger vision of the educational process.

The majority of students hunger for the larger educational process, the magnificent vistas of a greater reality beyond themselves which it presents, and the assurance it gives them that they are a functional part of the larger universe. Their appetite is dulled by a survey course in science which consists of a bushel of facts from astronomy to zoology, guaranteed to be of use in the home or in the office. Likewise the humanities. Never let students be told that fundamental laws underlie all the facts of science and that these are equally applicable to human affairs. The contact with philosophy—which should enable the student to achieve his own unifying picture of nature—is usually so limited that he comes away with the fuzzy information that Aristotle married a wealthy widow, that the name of Socrates' wife was Xantippe and he was a witch and she was a bitch, that you can't understand Kant, and Spinoza was in a whirling drunk because he became intoxicated with God.

Such a pair of educational stilts is supposed to lift the student to the level of higher learning if he is preparing for professional training; and he is thereafter supplied with a forest of spikes of specialized knowledge which convert him into a mental porcupine but not into a thinking machine that could develop into a master mind, which should be the primary prerequisite for attaining professional status.

The typical liberal arts training which limits the student to the concept of man-made authority is an anachronism; it is out of harmony with the spirit of the times and inadequate to meet the needs of the present and ensuing situations. It must be made permissive for students to think there is a possibility of some-

thing available to them which is more fundamental for guidance than the evanescent vagaries which emanate from the type of leadership now considered adequate to administer the executive aspects of human relations.

The executive type of individual is, and will continue to be, an essential part of our system. His troubles arise from his lack of knowledge that we live in a cosmos and that there is an authority which transcends his will. If this latter viewpoint were accepted as a basis for planning and operation, the strength of the executive's decisions would actually be re-enforced by the additional powers that would come from being in harmony with natural processes and this would be a valuable return for making a departure from present self-centered viewpoints.

It is necessary that executives be supported in such an approach by associates and subordinates thoroughly versed in the scientific approach to problems, and by a citizenry made equally aware of the responsibilities and added powers which come to those who accept the cosmos and so direct their thoughts and actions. This is the task which lies ahead in training tomorrow's brains.

Since it is the engineer who carries the burden of applying scientific knowledge to the solution of human problems, some thought may be focused on the situation in the field of engineering education. Efforts are being made to broaden the scope of the engineer's academic training by including the humanities in the course of study. The material available, however, is the typical liberal arts college material. The step is in the right direction. What is needed, however, is a sociology and an economics engineered and co-ordinated so that their every element is on a quantitative basis in the same framework of energetics, dynamics, and kinetics as the physical sciences, so that they indicate the same responsiveness to natural laws and natural forces, and recognize the same necessity for immediate and complete disclosure of all facts.

In due time we will be training engineers to chart and con-

trol the social strains and stresses in a community without regard to any given set of political principles or party interests. Likewise will be charted the tensile and compression strains and mass movements within the economic milieu, to indicate measures to establish equilibrium. Legislation will go on an engineering-guidance basis. Production, in its larger aspects, will go on a service basis with profit as a poor secondary consideration well under the control of the economics engineers.

In order to achieve this goal it will be necessary to produce men dedicated to the highest order of service and this calls for teachers and pupils fired with inspiration and ideals. The personality requirements for those who are to become engineers will be moved to increasingly higher levels. At the present time the hurdles which the aspirant must clear are being made higher and more numerous. It is becoming more difficult every day to become an engineer.

It was a whole lot easier for the famous names in engineering today to get through their school training than it is going to be for their successors. School training is the easy part of the task of becoming an engineer. An engineer never stops learning to be an engineer. The greater difficulties of the engineering courses today compared to a generation ago comprise the added knowledge contributed from the practical experiences of the engineers who entered unexplored realms of design, construction, and development, and got their information the hard way. The students of today, when they enter upon their larger responsibilities, will do the same for those who come after them. A diploma is nothing but an earned pass to the field of experience where knowledge is gained without the aid of a teacher.

There is never a dearth of ideas for development programs when men start to think. Carrying out any of these programs requires the employment of many men and expenditure of much money, and it would require only a few of them to overtax the facilities available in even our largest organizations. John J. McCarthy, at one time director of the Bell Telephone Labora-

tories, usually experienced an avalanche of such ideas from his staff. As a first step toward making a selection he would require definite answers to three questions: "Must this be done at all?" "Must it be done at this time?" "Must it be done in this way?" The replies usually made it possible to reduce the number of projects requiring immediate consideration.

The biggest names in engineering have raised the question as to whether engineering really is a profession. Whether it is, or is not, could be determined by a survey of the engineering schools as well as by observation of the practicing engineers. Inspired teachers produce professional men but plodding pedagogues produce only paid practitioners of an art. Inspired students can, however, rise above a low level of their teachers and, through their enthusiasm, act as class catalysts. Unless the students are galvanized by high-potential ideals of service the illumination of the professional attitude will not be achieved.

Heretofore anyone who could negotiate the tuition and meet minimum educational requirements could gain admission to an engineering school. Now, and to a greater extent in the future, the candidate will have to surmount personality, aptitude, capacity, and purpose tests.

There is a high mortality in professional development all along the line in the engineering field. The survey made by the American Society for Engineering Education revealed that out of one hundred students who entered the freshman class, only sixty appeared in the sophomore class and thirty graduated at the end of the four-year term. Government statistics show that among engineers over forty-seven years of age twenty per cent have left engineering for other activities. An inquiry into the causes of dismissal from engineering jobs revealed that personality deficiencies were the cause in sixty per cent of the cases, and deficiencies in technical knowledge in forty per cent.

The Engineers Council for Professional Development has undertaken a campaign to reduce this high mortality rate as a part of a broad program whose immediate objective is

Development of a system whereby the progress of the young engineer toward professional standing can be recognized by the public, by the engineer himself, and by the profession, through the development of technical and other qualifications which will enable him to meet the minimum professional standards and also to take his full place as a responsible citizen of the community.

THE PROGRAM is divided into four phases:

First—Continuing study of the processes by which young men and women, who seem to show interest and promise of success in engineering education, may be guided with some assurance into an engineering career; conversely, an effort to insure that those who do not have the desirable qualifications may advisedly be warned against attempting such a career.

Second—Co-operation between the practicing profession and the engineering schools and colleges. At the present time this phase is largely occupied with the far-reaching program of evaluating, for accrediting, the curricula offered by the various educational institutions, in fulfillment of requirements for engineering degrees.

Third—Establishment, development, and maintenance of appropriate programs of post-graduate college training through which the young engineer may keep up with rapidly moving technical developments while he is accomplishing his professional apprenticeship in practical experience.

Fourth—Creating an effective correlation among the various methods and criteria of recognition of the evolutionary development of the individual engineer.

THE COUNCIL published a thirty-six page pamphlet—"Engineering as a Career— A Message to Young Men, Teachers, Parents" —which has been distributed to the extent of about twenty-five thousand copies a year for ten years. A copy can be obtained for ten cents from the Council (33 West 39th Street, New York City). The pamphlet is aimed at both encouraging and discouraging those considering training for the engineering profession.

An inquiry has been under way for several years to determine the exact factors in an individual which indicate probable success and which indicate the advisability of trying other fields. Students, faculties, engineers, industry are being given an opportunity to make their contribution to the standards test. There

is no unanimity among all the groups concerning any factor. Mature engineers (80 per cent), for example, gave intelligence as top or second place rating, but when 260 freshmen were asked to state the most desirable characteristics in an engineer, only 57 per cent gave intelligence this rating. A tentative test has been arranged and, during the past year, states the 1947 report of the Council, the "Pre-Engineering Inventory" has been applied to 25,559 students in thirty-nine institutions. Another indicator has been prepared, the "Engineering Achievement Tests," designed to measure the proficiency of the student when halfway through his college course, and is being made available to institutions for use in the sophomore year to determine the advisability of the student's continuing in the engineering field.

Improvement of the engineering schools by setting minimum standards for teaching, equipment, and curricula, has been a major activity of the Council and has met with great success. In 1947, it was able to accredit the curricula of 74 per cent of all engineering schools in the United States. The basis of accrediting includes:

> Survey and analysis of the experience and attainments of the faculty, the standards and quality of instruction, the number and scholastic performances of the students, the records of graduates, attitude and policy of administration, curricula offered and degrees conferred, age of the institution and of individual curricula, requirements for admission and graduation, the physical facilities and finances of the institution.

SINCE the various state licensing boards use the Council's accrediting in fixing the educational requirements for legal registration the program has been very effective. As of October 1946, some 580 curricula have been inspected, evaluated, and accredited at 133 of the 167 engineering degree-granting institutions in the United States; 98 curricula had been examined but not accredited. The Council is extending its co-operation to

Canada and South America where extensions of the project are under way.

No action is taken by the Council on the content of the curricula. Such action is avoided in order to prevent any trend toward standardizing engineering education into a rut. It is desired to encourage progressive experimentation on the part of the schools and to leave them free to make adjustments to developing situations. The rapid expansion of scientific research and the production of new knowledge which has been incorporated rapidly into engineering techniques make it necessary to keep engineering education in a highly flexible state.

Up to 1900 the technical education of an engineer was a relatively simple matter. All that was required was the civil engineering background with a couple of auxiliary courses to take care of the specialized novelties—railroads and electric lights and motors.

Today the Council has accredited curricula in these departments of engineering: aeronautical, agricultural, architectural, ceramic, chemical, civil, electrical, fuel technology, general, industrial, mechanical, metallurgical, mining, naval architecture and marine, petroleum, and sanitary.

The ideal technique for educating a man is a perennial problem. Its complexities will defy any permanent solution if education is considered a process of pumping a man full of facts which may be pertinent to his very uncertain future activities. If education is considered a process of teaching a man how to think and to tap sources of knowledge, the situation becomes more hopeful.

It might be well for educators to meditate upon the fact that no atom ever made a mistake. A carbon atom in a piece of coal knows how to combine with oxygen, what radiation to emit in the process, what temperatures and what dimensions to exhibit. If that same carbon atom were placed in the sun it would know how to unite with four hydrogen atoms to produce and give birth

to a helium atom and in the process transform some of the latter's mass into energy which it will give off in the form of radiation of the right wave length. If the same carbon atom were placed in a plant on the earth it would know how to take part in the process of absorbing the radiation from the sun and applying it to the process of separating carbon and oxygen, and hydrogen and oxygen, united in the chemically dead compounds, carbon dioxide and water, and building them into high energy food compounds. If that same carbon atom were placed in the germ cell in a human being it would know how to take part in the process resulting in an individual, who would become an engineer, out of carbon, oxygen, hydrogen, and an assortment of mineral atoms. These, and other remarkable feats, can a carbon atom perform, yet no carbon atom ever attended an engineering school, nor has any carbon atom ever found it necessary to confer with a professor, consult a handbook, set a slide rule, or make a working drawing before going into action.

The old materialistic doctrine that the carbon atom had no choice is no longer applicable in the light of the modern development in physics in which a reaction is no longer a path to a particular point but to the totality of a pattern of probabilities in which each atom taking part as if it were thoroughly conversant with the entire pattern and knew its particular function in making any part of it.

The engineer will continue to direct his activities as if the reaction were directed to the old-fashioned point which he will measure with the required degree of approximation to suit his needs, but the new idea will continue to penetrate ever more deeply into engineering and all other fields of education bringing about fundamental changes in our viewpoints concerning the basic nature of knowledge, and the process by which we acquire it, our viewpoints of nature, of ourselves, of the limitations and unmeasured possibilities of our individual identities and our relations to the community we serve.

A four-year course in engineering, following grammar and

high school, will not make an educated man: It will not produce a professional man. It may produce a walking handbook. A real professional man, in the light of the requirements of the new age which is dawning, will be one who has received such an all-round education that he could, in a minor capacity, enter directly into law, medicine, theology, science, or engineering, and, with more specialized training, become a master in any of them.

The four-year college course has been the standard since the days when the average life span of man was thirty-five years. Today the life span is nearer sixty-five, a net gain of thirty years. We can afford to invest a portion of the longer life span in a more extended period to acquire the knowledge demanded by the life that has grown more complex as its years have increased in number.

Dr. James Bryant Conant, President of Harvard University, in his current annual report declared,

> The real general education of any man is the life's work of the man himself.

Dr. Harvey N. Davis, President of Stevens Institute of Technology stated the following in a recent annual review.

> The times demand that engineering institutions turn out broad-gauge men who will not only blueprint the future, but will play a leading part in building a better world in which technology will face demands and opportunities greater than it has ever faced before. The goal of engineering education is not merely professional efficiency, but a liberal education for life today and tomorrow.

E. C. Wright of the U. S. Steel Corporation (National Tube subsidiary) had this to say in an address at a meeting of the American Institute of Mining and Metallurgical Engineers:

> It has been the general and continued observation that most (engineering) students employed had inadequate training in such fundamental sciences as physics, physical chemistry, thermodynamics, and mathematics higher than simple calculus, all of which are essential to

good work. . . . By the present training schedule at least five years of practical experience following four years in an engineering school is desirable in developing a good metallurgical engineer.

He saw the possibility of reducing the total training period to seven years, if part of each year's study period were spent in industrial work.

In the universities, there is an insistence that the student lay a broad foundation before entering a specialized field. Two or three years' majoring in English, economics, history, literature, philosophy, or social or economic studies is required as a prelude to two final years in engineering. Post-graduate work for an M.S. or a Ph.D. degree, or in post-graduate researches, can extend the education period as desired.

Dr. T. L. Joseph, assistant dean at the Minnesota Institute of Technology, has proposed a five-year course, which is the four-year engineering course extended in time to include the equivalent of a year of a liberal arts course. The segments and subjects of the liberal arts course are distributed: First year: Communication, agencies of communicating ideas; practice in communication, written and oral. Second year: Life science area; general biology. Third year: Social science area. Fourth year: Humanities; history, social criticism, literature, fine arts, and philosophy. Fifth year: Advanced engineering, English, and electives.

Massachusetts Institute of Technology, the giant and outstanding leader among engineering institutions, where, at the present time, every state in the union and forty-six foreign countries are represented in its student body, has taken the lead in broadening the base of technological education. Its program is expressed by its president, Dr. Karl T. Compton, who recently resigned to become director of the Office of Scientific Research and Development:

The far reaching effects of science and engineering in modern life place a heavy professional and social responsibility on scientists and engineers, and the institutions which educate them must aid in the

development of a high standard of public service. The educational program of M.I.T. recognizes this as a prime objective. Its augmented and vigorous programs in the humanities, its outstanding work in the social sciences, including economics, labor relations, and international relations, and its expanded services for student counseling, student health, and student activities—all combine to widen the base of professional education. The objective is to train top-flight engineers and scientists who are likewise top-flight citizens, who have background, understanding, and public spirit, to be leaders in their profession, their neighborhoods, and the nation.

Dr. Davis, of Stevens Institute of Technology, sees the present trend in engineering education as vindication of the idea which has been stressed in that organization since its inception.

Our graduate school is our recognition of the fact that academic training for the profession of engineering is steadily going over to a graduate basis. More and more the technical profession of engineering is becoming, not an art, but a mathematical science. More and more of those who hope to practice engineering as such will need more, both of modern science and of the humanities, than can be compressed into a four-year undergraduate training. Our broad undergraduate curriculum supplemented by specialized graduate training at night, while a man is holding down a job in the daytime, is our way of meeting this problem. Our graduate enrollment is already two-thirds as large as that in the college and it will undoubtedly grow rapidly in the post war years.

When Peter Cooper, millionaire industrialist, founded Cooper Union in 1859, he provided in his deed of trust that the instruction should not only be on the application of science to the useful occupations of life, but also

on social and political economy, and the science and philosophy of a just and equitable form of government based on the great fundamental law that nations and men should do unto others as they would be done by.

Dr. Gano Dunn, President of Cooper Union, a pioneer in the practical application of these principles to engineering education and practice, when a vacancy occurred in the office of director of the school, held it open for a protracted period, not

because engineering educators were not available, but because he was waiting to find the man who was the humanist as well as the engineer. It seemed like an impossible combination but he found him in Dr. Edwin Sharp Burdell, who was a graduate of M.I.T. and of the Harvard Graduate School of Business Administration, had taken other graduate courses, had had actual experience in government administrative posts, had returned to M.I.T. as professor of sociology and later as dean of the humanities. He was appointed director of Cooper Union in 1938.

Dr. Burdell states in his 1947 annual report:

> We believe that regardless of the skills and information imparted to the students, the teachers have an even greater responsibility—the students' cultural and spiritual enlightenment. . . . It is gratifying to note that the students welcome such courses and ask for more, rather than less, subject matter in the non-technical fields.
>
> An interesting outgrowth of this nation-wide trend to introduce humanities into engineering education is that the scientists and engineers, in order to make room for these additional subjects, have consolidated and simplified the instruction in science and engineering. Emphasis is now placed on the fundamentals and the specialties in the upper years are relegated to the graduate school or to instruction given by industry as part of the on-the-job training.

The American Society for Engineering Education has been urging the adoption of the broadened base and recently recommended that curricula be rearranged so that twenty per cent of the course will be devoted to the humanities.

We appear to be surrounded today with almost insuperable difficulties in solving the problem of providing an all-round education for those who must serve as leaders. Perhaps our difficulties are relative rather than absolute in their magnitude. It seems from our vantage point as if the situation involved no difficulties one hundred years ago. Nevertheless, we find John Stuart Mill writing—a century ago:

> Every department of knowledge becomes so loaded with details, that one who endeavors to know it with minute accuracy, must confine himself to a smaller and smaller portion of the whole extent. . . .

Now if, in order to know that little completely, it is necessary to remain wholly ignorant of all the rest, what will soon be the worth of a man, for any human purpose except his own infinitesimal fraction of human wants and requirement? His state will be even worse than that of simple ignorance.

IF THAT is the way the situation looked to Dr. Mill before the days of electrical power, airplanes, subway, radio, what would he say if he could return today? To him the man of highly specialized knowledge was a total loss to the community. He was living in the days before the technical man, specialized through his knowledge, created the social and economic environment to which he could make contributions of tremendous community value and from which he could derive social and economic values amply to justify his existence.

It would be unfortunate if technical education became so specialized that it outgrew the university. It is highly desirable that a closely linked liaison be maintained between the scientific and engineering schools and those associated with other professions. The scientists and engineers are at a much higher potential of advancement and it is time that the isolating barriers were punctured and an oscillating current, bringing an interchange of knowledge and viewpoints, took place between them.

When a man is isolated in a specialty for a long time and makes contact with someone in a related field and learns of developments in that field analogous to those in his own, giving him a new link with the outside intellectual world, he experiences almost a state of ecstasy and revelation which is the equivalent of a cultural "shot in the arm." He is rejuvenated. When this happens in the course of fundamental education in college, it brings a broader vision to the student, a new enthusiasm for worlds to conquer and engenders a greater imagination for the application of knowledge. These qualities are essential in the man who is going to achieve professional status in engineering quickly.

Leonardo da Vinci was an engineer and an artist with a mag-

nificent imagination. His genius ranged over a tremendous field of accomplishment. Even such a gigantic intellect as his can, nevertheless, get into a rut and miss one of the greatest achievements of all time—the invention of the steam engine. He was interested in power development and power applications, all the way from water-power, through a chimney draft windmill to turn a roasting chicken, to a man-power-operated automobile. His patron duke, however, was interested in war and Leonardo's attention was diverted to making war engines, rock throwers, wall scalers, and something akin to modern tanks. One of his most interesting war inventions, however, was a steam cannon—a metal cylinder, into which a tightly fitting projectile was held by a latch. This cylinder contained water in its lower end which was heated by an outside fire, and when the steam pressure was adequate the latch released the projectile. Here, about 1550, Leonardo held the steam engine in his hands and did not recognize it. In other devices which he previously contrived he had all the mechanical motions required to provide him with a reciprocating engine which would produce rotation, the lack of knowledge of which delayed Watt's progress centuries later.

We should have had the steam engine nearly nineteen hundred years before Watt and Newcomen. Hero of Alexandria developed, in the second century B. C., not only a simple steam turbine but cylindrical steam pumps which performed a variety of functions. They were used almost entirely as automata in the temples and palace, to open doors, operate fountains, and do other trivial things. Their ability to do work was obvious and was demonstrated, but with so many slaves available to do work, why should anyone bother to make mechanical devices to do what the slaves did so cheaply? If Egypt had not stooped to the crime of slavery, she might have developed the steam engine and become the economic master of the world. What a different history this world would have had during the past two millenniums! The point in connection with this story is that if the scientists and engineers are going to develop a high technical

world-machine, they will have to take steps to see that the world provides the right kind of a social and economic environment in which it can survive. The engineers who will have to carry on that project are in the schools today. It is up to them to develop that professional type of imagination which will provide them with solutions of these broad-gage problems. If wise, they will go to nature for the answers to their questions. They will learn to think about things as well as tinker with things. Nature speaks a simple language and always gives truthful answers.

Mathematics is a language which is much closer to nature than English or other languages. It is a language in which the words are magnitudes, time, and direction. Most of our sciences are really nothing but special languages. Physics is a language in which the words are masses, energy, and motion. Chemistry is the language of atoms and molecules. Architecture is the language of aesthetic forms. Nature is speaking to us through these languages.

The engineer is, in a sense, learning the languages of the sciences and translating them into the language of man and his relations to nature. That, in its simplest form, is what the engineering student is learning to do.

23. BUILDING A WORLD VIEWPOINT

THERE IS no technique known to engineering by which the gigantic skyscraping towers of the George Washington Bridge could be transported as a completely fabricated unit from the steel mills of Pennsylvania to the banks of the Hudson River. By transporting them in small pieces and assembling them at the site of the bridge, the same result is accomplished. This technique is one of universal application. It is particularly useful in human affairs and should be kept in mind when we get the idea that some jobs involving human situations are too big or too complicated for practical handling.

In the hands of master technicians great effects can be produced by moving small units under a preconceived plan. A project that could not be put across as a totality can be put across in small units without arousing the antagonism that the completely presented project would arouse.

For thousands of years civilization has been on a basis in which achieving progress was an art in which man had to sense the right direction of progress and adjust his course as best he could to his interpretation of where his goal lay. There was no standard which could be used to judge whether the effects in a teleological sense were good or bad. Survival or non-survival was the practical test. He who, through his efforts, was able to provide survival for himself, even at the cost of non-survival to others, was, according to his standards, achieving the most desirable results and fully justifying his course of action.

Modern man still lives in a society where an excess of benefits exist for one individual, even at the expense of a lack of benefits for others. In a civilization in which there is no other mecha-

nism available for maintaining order than physical might, the mighty man—physically—the extreme type of extrovert, is the ideal man for administering the affairs of a community.

Times have changed. Within the realm ruled by the mighty man, there has grown up a new conception under which men find a more satisfying guidance in the laws of nature and a safer allegiance in worshiping truth. Nature rewards those who worship her in truth by granting to them control of natural forces vastly greater than those that ever came under the control of any mighty man of history.

The mighty man by his very nature is incompetent to discover the laws of nature or to worship truth. He can, however, under his might-makes-right technique, control the men who discover the laws and control nature's forces and thereby direct the benefits for the maintenance of his own rule. During a transition stage this technique could be successful.

Today our entire civilization is built on the forces of nature and the responsibility for its maintenance rests upon those who are competent to discover them and control their application. The mighty man, never gifted with farseeing vision, is going blind. His extroversions were never intelligently directed, and he is now using the forces of nature as he formerly used his brute strength. He is smashing the machine of civilization through his wars, but refuses to yield control and refuses to take lessons to learn how to drive it. "Easy does it," says the scientist and engineer. "Smash 'em," says the mighty man, "and if you don't stop trying to tell me what to do, I'll smash you, too, but if you are willing to keep the machine running and build some more and let me do as I wish with them, I'll pay you well."

An entirely new type of mind is required to operate our technical, power age civilization. The time has come for the rule of the mighty *minds.* The mighty man, however, does not want to retire, or yield an iota of his control.

Just as the giant towers of the George Washington Bridge were erected piece by piece, so is the mighty man seeking to

build up control of the mighty minds. The engineer's allegiance, through his original prototype, the military engineer, is to the mighty man, although the engineer is himself the progenitor of the mighty mind which has flowered so magnificently in the field of science. The engineer's stock in trade is the application of science for practical purposes. The money for paying him for doing so comes through the mighty man, in politics and industry.

The mighty man is not suited to be the executive of a power age civilization; to understand its nature or manipulate its controls. He can, however, render an extremely useful service in the community under the direction of those who created the machine and do understand the forces at work. The mighty man is clever and shrewd and knows a lot of time-tested tricks designed to keep himself in power through control of the money bags. These techniques can be more usefully applied for other purposes.

Technology, science, and engineering combined, during the past half century, have tremendously increased man's productivity to such an extent that the mighty man was able to siphon off the benefits for his purposes so that he could use tremendous quantities of the wealth produced to fight two gigantic wars. With the mighty minds under his control, he was able to indulge in a profligate waste of the wealth of the human race and the destruction of much of mankind's goods. If the mighty minds said "No," the mighty man would have been helpless. The mighty man is clever enough to know that he must never risk the danger of a "No." The application of such cleverness, however, may not operate for universal good.

The source of technological power is centralized in the universities, colleges, and in the associated institutions, and in the men who study at these institutions and become the technical men. Control of the universities and other schools would give control of the power of technology. In the past, the schools which produced the scientists and engineers were supported largely by

private philanthropy, the tuition payments of the students yielding but a small fraction of the operating expenses.

The wastage of the mighty man's war was paid, in part, by siphoning off the wealth which formerly would have been devoted to civilian constructive purposes under which the educational institutions were chief beneficiaries. With this source of support gone, the universities are in a difficult position. The mighty man's solution is to make the support of the universities a government function. This process is now under way.

For the control of individuals, the G.I. Bill of Rights provides that an important fraction of the next generation of technically trained men will be beholden to the government for their education. In the past, a large proportion of the civil engineers became government employees. Now the government is absorbing increasing numbers of all engineers for army, navy, and other federal agencies.

The government money for the training of these men goes to the universities and colleges. Research and development activities for war departments bring further income to the schools. The G.I. tuition money will stop in the very near future. Due to the war-caused devaluation of money the income on endowments held by the schools has dropped to about one-third of pre-war levels. The financial situation of the schools will not improve. They are raising tuition charges, increases of 30 per cent to as high as 60 per cent already being in effect. Further increases will be imperative. Continuation of international bungling and domestic techniques by which the mighty men maintain their control will not diminish, and the siphoning of wealth for these purposes will continue, which will mean the end of private philanthropy and an increasing inability of the population to meet the increasing costs of higher education. This means further government money and further control. Any university or other school which exhibits a cool attitude toward the government's expenditures and control measures is likely to find its curriculum unsuited for educating G.I.'s and it will

not receive the benefit of any government expenditures. No one institution is in any position to take a critical attitude. Should any institution be reckless enough to oppose the trend, every agency of government would be directed toward discovering that the institution was a hotbed of reds and other subversive elements.

Under private control of educational institutions it has been possible to maintain the Jeffersonian ideal of education, under which provisions could be made for developing exceptionally gifted individuals. Under government control, the Jacksonian system prevails—mass production of a stereotyped training, regardless of its adaptability to the individual. It is education of the individual to the extent to which he will be of most use to the state with the least expenditure of time and effort. Those selected for education under this system are indebted to the political powers for this benefit and, naturally, favor continuation of the system which aided them. Under the Jeffersonian ideal, education is suited to the individual and its course is not limited (at least in theory) to the support of any ideologies.

There is no doubt whatever that the cost of education is a responsibility of the community. Every individual should be educated at public expense. There is a vast difference, however, between this and government ownership, which means political control of the country's educational facilities. The primary purpose of education is enhancement of the happiness and evolvement of the individual, and every individual is entitled to such education as will increase his satisfaction with life, within the limits of the facilities available. It is then the responsibility of the individuals to determine how they wish to organize their community life.

The scholars are the trustees of knowledge. All men in all times have contributed to our fund of knowledge and the contribution was made for the benefit of all men in all times. Its trustees should so administer it. It is the privilege of scholars to determine how mankind's fund of knowledge shall be applied.

All those who avail themselves of the fund of knowledge by receiving extended instruction assume a professional obligation to use it properly, and under the ethical code of the professions and scholars who made it available.

The existing fund of knowledge is the heritage of the entire human race. No portion of the human race has the privilege of using it to injure other members. The trustees of knowledge hold a responsibility for so administering it that it will not be misused. Under this responsibility they are required to recognize the nature of their world-wide organization and to act under the balancing liberties and duties inherent in it.

Knowledge is the common possession of all men. It is the language of the common nature of man and his universe. It is the basis of the professional status in all fields. Knowledge is the voice of God, sometimes not accurately translated. This ideal, however, is the safe guidance for working out our problems in human welfare. The extent of our knowledge is an index of the degree to which we are advancing along the path of progress. Ahead lies a fund of knowledge immeasurably vast compared to that which has been revealed to us. All knowledge is acquired by processes of revelation, even though the details of the process may blind us to the basic nature of the mechanism by which we achieve it. There is no monopoly in achieving knowledge. There is a source of fundamental knowledge where exists the understanding of all things. Every atom in our bodies may be a doorway to this temple of ultimate comprehension, for each one of them contains a blueprint of the entire cosmos. The configuration of our bodies is in every atom, the pattern of our individual lives and of our community existence is exemplified in the resonances and harmonies of both the microcosm of the atom and the macrocosm of the universe.

When utilizing our expanding knowledge, we should lay the foundation stones for the structure of world-wide understanding and co-operation among men. The responsibility for erecting this temple rests with the trustees of knowledge, the

scholars, whose academic homes are the universities and other institutions of higher learning. These are the nuclear structures for the world-wide network out of which will crystallize the functioning organization. From its nature and purpose the organization would be an ultraversity, that is, an organization for moving the race upward and onward. Its authority would rest in nature and would not be derived from any man-made organization.

The ultraversity would be the fulfillment of the aspirations of Pythagoras who hoped for, and partly succeeded in establishing, a world university, and of the vision now somewhat dimmed but seen clearly by the founding fathers of the church and now capable of rounded completion. It would be the intellectual and spiritual home of the professions of theology, medicine, science, and engineering, and in time of all others which sent their roots down into nature for their spiritual and intellectual nourishment, and abjured man-made laws of selfishness which justify aggrandizement of strategic individuals by unfair administration of facilities under their control.

The ultraversity would be to the peoples of the world what a real universal United Nations would be to the political powers. The present United Nations is the dying gasp of the rule of the men whose might makes right. The ultraversity must begin to function that we may have a straight line, orderly transition from the older order to the new. The new order is inevitable, and there is no magic in words that can talk it out of existence.

Within our own country the course of transition is a simple one which should encounter no opposition from anyone desirous of the welfare of our nation and who wishes for it a course of progress which will bring enlightenment to the world by an outstanding example of courageous leadership in the right direction.

No country of the world has a greater number of universities, colleges, schools, technical and research institutions than the United States; nor can their executives and faculties be matched

anywhere for their devotion to truth and democratic principles of life—individual and community. The maintenance of these institutions is now a problem under an inadequately engineered economic arrangement. They should and will be supported and expanded as a public expense but not under political control. They will furnish the nucleus of the ultraversity. The expense of their operations under a program in which they, as the trustees of knowledge, will undertake their full responsibility will be determined and this amount will be collected as a federal income tax. The expenditure of the money so collected will not be under the control of Congress. An accounting of its expenditures will be made, more complete and frank than any ever made by a political body. The funds collected will be adequate to permit the ultraversity in the United States to aid the organization throughout the world to attain similar fruition.

The ultraversity so organized will share with the political organizations the responsibility for achieving world-wide cooperation of all men. It will proceed on a factual and truthful basis to establish equilibrium throughout the human race. Political bodies will not engage in any activities pertinent to a problem, but will seek the recommendations of the ultraversity and will subsequently act in the light of the solution presented by the ultraversity. The procedure is simple and very economical compared to the costs of the techniques we are now using, with unsatisfactory results, in handling world affairs.

The motto of our country, "In God We Trust," is in complete harmony, at least in purpose if not in words, with the ultraversity and its program. The primary allegiance of all men is to God—and this introduces no conflict with allegiance to country.

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